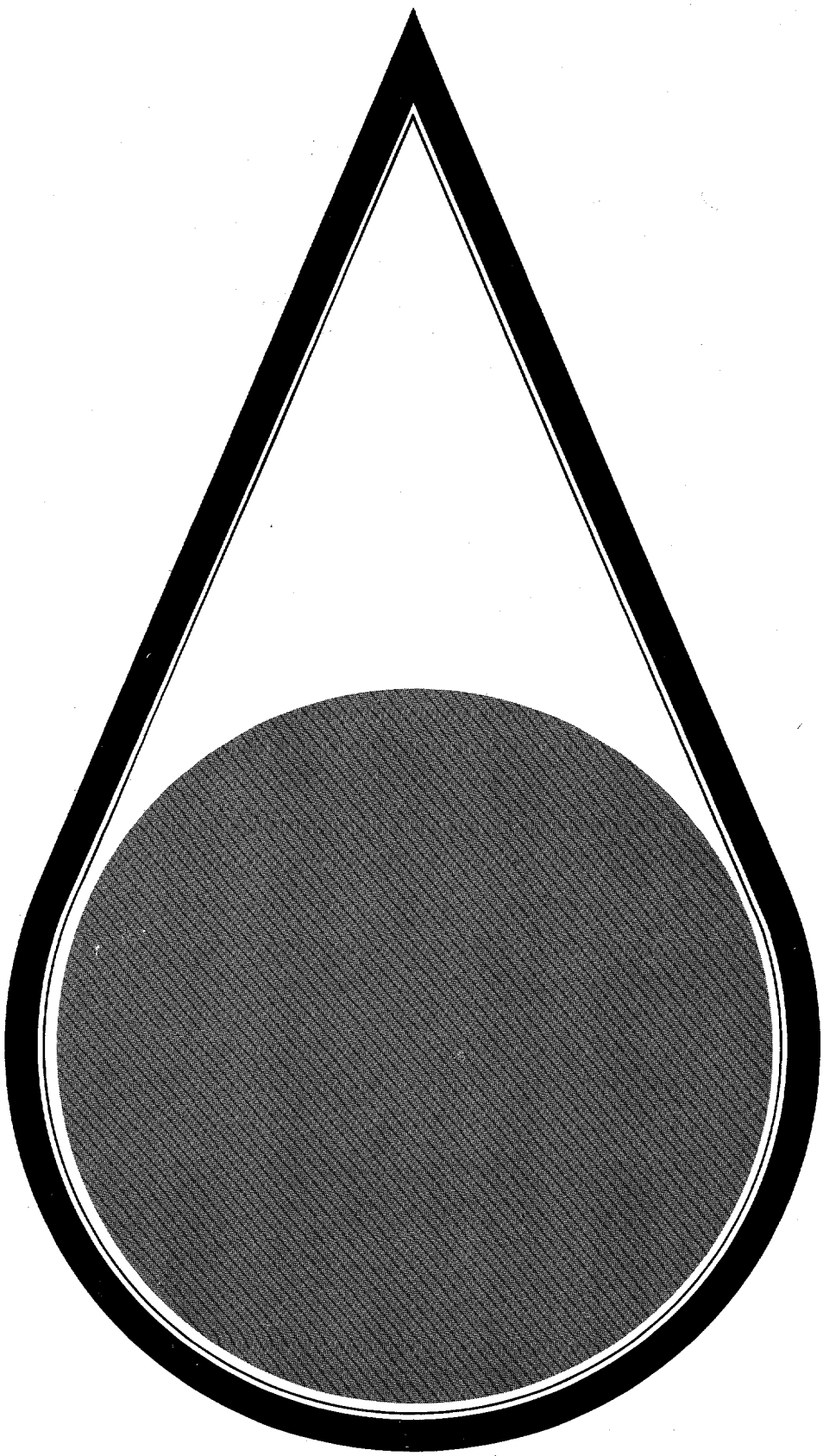
INSTREAM CONTAMINANT STUDY - TASK 2
SEDIMENT CHARACTERIZATION
VOLUME I

Office of Natural Resources
and Economic Development
Tennessee Valley Authority



ChemRisk Document No. 841

SEDIMENT CHARACTERIZATION

TASK 2

INSTREAM CONTAMINANT STUDY

Prepared for

U.S. Department of Energy
Oak Ridge, Tennessee
Under Interagency Agreement No. DE-AI05-84OR21444

Office of Natural Resources and Economic Development
Tennessee Valley Authority
April 1985

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TASK 2

SEDIMENT CHARACTERIZATION
INSTREAM CONTAMINANT STUDY

1.0 INTRODUCTION

On November 3, 1983, the Oak Ridge Task Force under direction of the Tennessee Division of Water Management, approved conceptual workplans prepared by four subgroups of the Task Force. These workplans addressed potential offsite contamination problems associated with the Department of Energy (DOE) facilities near Oak Ridge, Tennessee. The conceptual workplans were transmitted to DOE on November 14, 1983. DOE subsequently authorized the Tennessee Valley Authority (TVA) to prepare a technical workplan covering the instream water, sediment, fish, and floodplain sampling approved by the Task Force (1). The Instream Contaminant Study workplan was submitted to DOE on February of 1984 and the work authorized by Interagency Agreement No. DE-AI05-84-OR21444, Contract No. TV-64095A, between DOE and TVA, and approved by the TVA Board of Directors on April 30, 1984.

This is the second of five task reports on the Instream Contaminant Study. It presents the results of laboratory analyses of sediment samples collected downstream of the DOE facilities. The samples were collected from June through November 1984. The Task 2 report presents the sediment data and the procedures for collecting, handling, and analyzing the samples. Results are summarized in graphs and tables that include available criteria, standards, and background levels. The procedures

and data are discussed for clarification but the implications of the data have not been assessed. All data are presented in Appendices I to V.

1.2 PURPOSE

The purposes of Task 2 of the Instream Contaminant Study are to define the floodplain for the maximum flood event during the period of operation of Department of Energy (DOE) facilities at Oak Ridge; to estimate the quantity of mercury contaminated sediment and floodplain deposits along East Fork Poplar Creek, Bear Creek, and lower White Oak Creek; to measure the concentration of other contaminants in sediments downstream of DOE facilities; and to obtain preliminary information on the possible transport of mercury contaminated sediment to the Tennessee River.

1.3 SCOPE

The sediment sampling program involved four basic activities. The first included cross section surveys and floodplain mapping to define the maximum flood event since 1940, the approximate beginning of DOE operations. Floodplain areas included the Clinch River from the mouth in Watts Bar Reservoir to Melton Hill Dam; Poplar Creek from the mouth at Clinch River Mile (CRM) 12 to mile 5.63 upstream of East Fork Poplar Creek; East Fork Poplar Creek from the mouth to mile 14.7 downstream of New Hope Pond; and Bear Creek from the mouth to mile 7.7 downstream of the S-3 ponds.

The second activity involved the analysis of mercury concentrations in sediment (i.e., 122 cores collected in the floodplain of East Fork Poplar Creek, 19 instream sediment samples collected in East Fork Poplar Creek, four cores collected in the floodplain of Bear Creek, and four instream cores collected in lower White Oak Creek). In addition, selected cores were also analyzed for radiological parameters. The floodplain sampling locations on East Fork Poplar Creek and Bear Creek were selected using the floodplain maps described above. Limited sampling of the Bear Creek and White Oak Creek floodplains was conducted to verify previous data (2) which suggested that mercury contamination was not extensive in these areas.

The third activity involved selective sampling of surface layer sediments at instream (i.e., channel bed) locations to determine the presence of other contaminants (i.e., base/neutral priority pollutants, priority pollutant metals, cyanide, phenols, PCBs, and radiological contaminants). Sixteen fine-particle sediment samples were collected from East Fork Poplar Creek, three from Bear Creek, four from lower White Oak Creek, three from Poplar Creek, five from the Clinch River (Watts Bar and Melton Hill Reservoirs), and three from Norris Reservoir (background samples).

The fourth activity involved core sampling in the Clinch River and Tennessee River. Eight core samples were collected from the Clinch River below Melton Hill Dam to determine the presence of mercury and

radiological parameters. Seven core samples were collected from the Tennessee River (Watts Bar Reservoir to Guntersville Dam) to determine the presence of mercury, PCBs, and chromium.

2.0 SAMPLING LOCATIONS AND PARAMETERS

2.1 AREAL EXTENT - FLOODPLAIN MAPPING

The floodplains of the Clinch River (mile 0 to Melton Hill Dam at mile 23.10) and Poplar Creek (mile 0 to 5.63) were defined by tabulating flood elevations at existing and newly surveyed cross section locations. On East Fork Poplar Creek and Bear Creek, flood elevations were tabulated and the floodplains depicted on USGS topographic maps at a scale of 1" = 400'. In order to supplement existing data, 20 new cross sections were surveyed (i.e., eight on East Fork Poplar Creek, two on Poplar Creek, and ten on Bear Creek). Culvert and bridge dimensions were obtained at 17 locations on Bear Creek. Table 1 indicates where new survey data was obtained.

2.2 MERCURY CONTAMINATED SEDIMENT SAMPLING

Sediment cores were collected at 122 locations along 30 transects (at right angles to the direction of flow) in the floodplain of East Fork Poplar Creek, and at four locations in the floodplain of Bear Creek. Instream sediment samples were collected at 19 locations in East Fork Poplar Creek and at four locations in lower White Oak Creek. Figure 1 shows the location of the sampling transects along Bear Creek and

TABLE 1

INSTREAM CONTAMINANT STUDY - TASK 2
AREAL EXTENT - FLOODPLAIN MAPPING - LOCATION OF NEW
CROSS SECTIONS FOR NATURAL GROUND, BRIDGE, AND CULVERT PROFILES

Natural Ground Cross Sections		Bridge and Culvert Cross Sections	
Poplar Creek Miles	5.29	Bear Creek Miles	1.08
	5.63		1.50
			2.78
East Fork Poplar Creek Miles	0.62		2.91
	1.35		3.86
	1.66		4.28
	2.85		4.90
	5.42		5.86
	7.05		6.20
	10.90		6.38
	13.55		7.01
			7.36
Bear Creek Miles	0.77		7.44
	1.64		0.39
	2.37		0.55
	2.62		0.92
	3.30		1.28
	4.58		
	6.63		
	6.93		
	7.20		
	7.74		

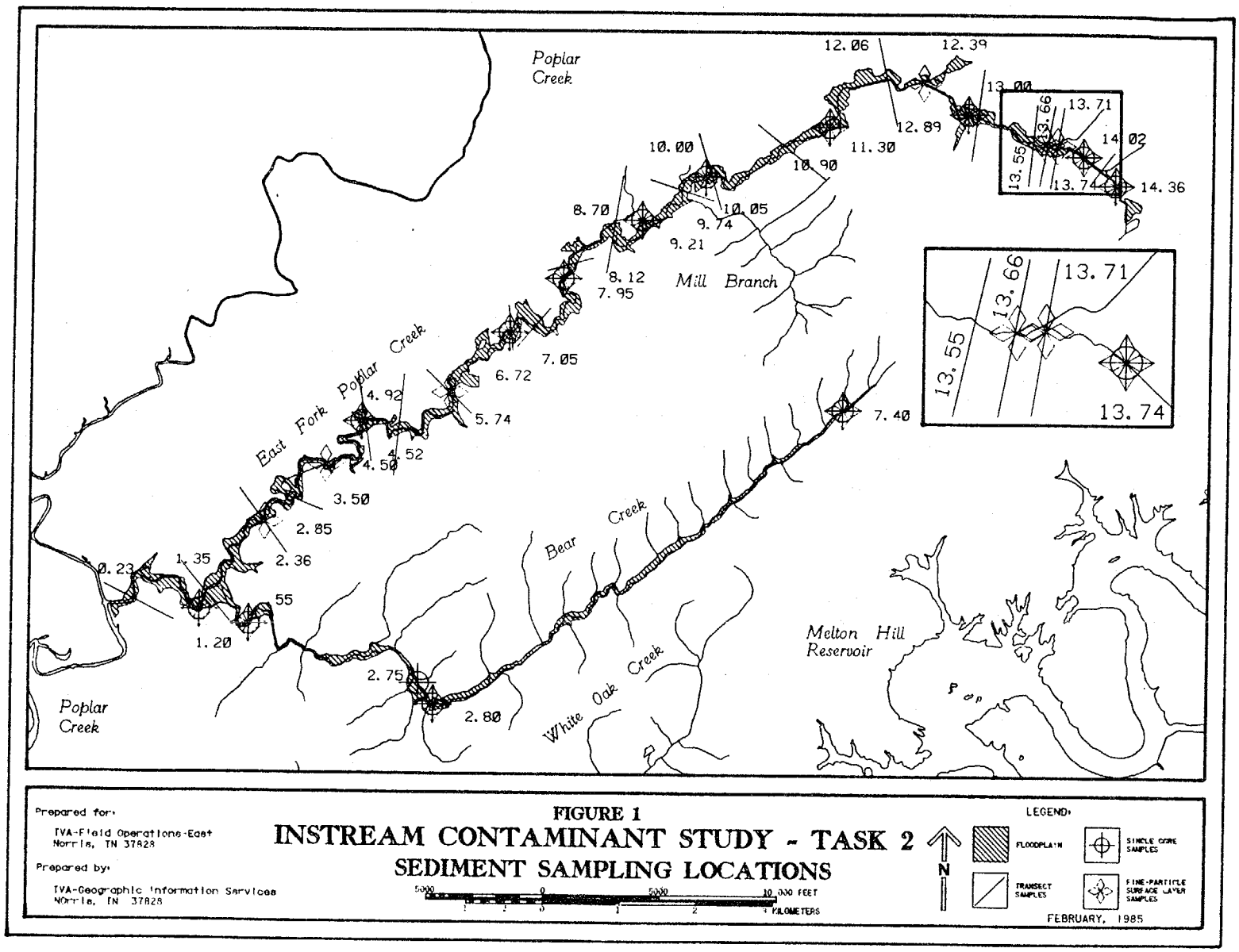
Poplar Creek
12.06
12.39
13.00
13.71
13.66
13.55
14.02
14.36
13.74
12.89
11.30
10.00
10.90
10.05
9.74
9.21
8.70
8.12
7.95
Mill Branch
7.05
6.72
East Fork Poplar Creek
4.92
5.74
4.52
4.50
3.50
2.85
2.36
1.35
0.23
55
1.20
7.40
Bear Creek
2.75
2.80
White Oak Creek
Melton Hill Reservoir
Poplar Creek
13.55
13.66
13.71
13.74
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FIGURE 1
INSTREAM CONTAMINANT STUDY - TASK 2
SEDIMENT SAMPLING LOCATIONS
5000 0 5000 10,000 FEET
1 0 1 2 KILOMETERS
N
LEGEND:
FLOODPLAIN
TRANSECT SAMPLES
SINGLE CORE SAMPLES
FINE-PARTICLE SURFACE LAYER SAMPLES
FEBRUARY, 1985

East Fork Poplar Creek. Figure 2 shows the sampling locations in lower White Oak Creek.

Sampling locations were selected using the floodplain maps, previously collected data, and information on hydraulic and hydrologic characteristics of the streams. Sampling was also staged and the initial results used in selecting additional sampling sites.

Sampling in Bear Creek was conducted on June 20 for mercury and particle size analyses and September 12 for radiological analyses. Sampling in White Oak Creek was conducted on August 29.

Sampling in East Fork Poplar Creek was conducted in three stages. The first survey was conducted on June 18-27 to obtain preliminary information on the distribution of mercury contaminated sediments. Based on the laboratory results, a second survey was conducted on September 18-25. The third survey was conducted on November 6 and 7 to further define the horizontal and vertical boundaries of the contaminated deposits.

Table 2 indicates the number and location of core samples along East Fork Poplar Creek, Bear Creek, and lower White Oak Creek. The number of sediment layers and duplicate sampling sites are also given for each location. Table 3 indicates the laboratory analyses conducted and the total number of samples analyzed for each parameter.

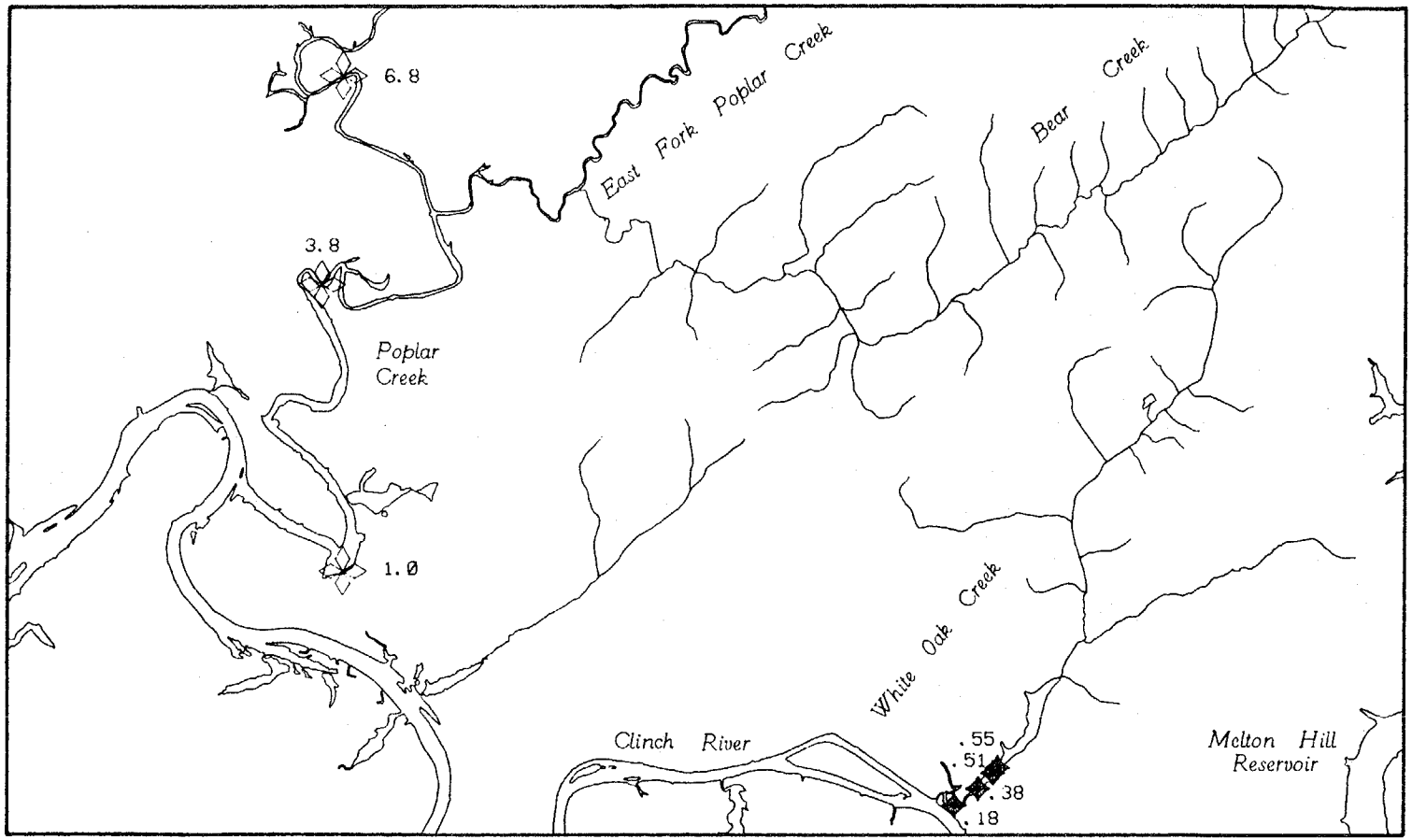

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FIGURE 2
INSTREAM CONTAMINANT STUDY - TASK 2
POPLAR CREEK AND WHITE OAK CREEK
SEDIMENT SAMPLING LOCATIONS

5000 0 5000 10,000 FEET
1 2 0 1 2 3 KILOMETERS

N

LEGEND:
CORE SAMPLES
SURFACE LAYER SAMPLES

FEBRUARY, 1985

TABLE 2

INSTREAM CONTAMINANT STUDY - TASK 2
MERCURY CONTAMINATED SEDIMENT - CORE SAMPLING LOCATIONS - EAST FORK POPLAR CREEK, BEAR CREEK, AND WHITE OAK CREEK

Transect Location (River Mile)	No. of Sampling Sites[1]			No. of Layers Sampled[1]			No. of Sites Sampled in Duplicate		
	Prelim. Survey	Intensive Survey	Contam. Bdy. Survey	Prelim. Survey	Intensive Survey	Contam. Bdy. Survey	Prelim. Survey	Intensive Survey	Contam. Bdy. Survey
				EAST FORK POPLAR CREEK					
14.36	1	0	0	1	0	0	0	0	0
14.02	0	3	0	0	5	0	0	0	0
13.74	1	0	0	2	0	0	0	0	0
13.71[2]	7	0	0	22	0	0	1	0	0
13.66[2]	6	0	0	13	0	0	0	0	0
13.55	0	6	1	0	18	2	0	0	0
13.00	0	6	3	0	11	9	0	1	0
12.89	1	0	0	3	0	0	0	0	0
12.06[2]	0	6	1	0	9	5	0	0	0
11.30[2]	1	0	0	3	0	0	1	0	0
10.90	0	7	3	0	18	10	0	1	0
10.05	0	6	5	0	10	13	0	0	1
10.00	1	0	0	4	0	0	0	0	0
9.74	0	5	0	0	8	0	0	0	0
9.21	1	0	0	3	0	0	0	0	0
8.70	0	6	4	0	9	16	0	0	0
8.12	0	4	4	0	7	12	0	0	0
7.95	1	0	0	2	0	0	0	0	0
7.05	0	5	0	0	8	0	0	0	0
6.72	1	3	2	4	9	9	0	1	1
5.74	2	1	0	4	1	0	0	0	0
4.92	0	4	3	0	4	7	0	0	0
4.52	0	4	1	0	10	3	0	0	0
4.50	1	0	0	4	0	0	0	0	0
3.50	1	3	0	2	5	0	0	0	0
2.85	0	5	0	0	12	0	0	0	0
2.36	1	3	0	3	5	0	0	0	0
1.35	0	5	2	0	8	9	0	1	0
1.20[2]	1	0	0	5	0	0	0	0	0
0.23[2]	1	3	0	2	5	0	0	0	0
TOTALS	28	85	28	77	162	95	2	4	2
	TOTAL = 141			TOTAL = 334			TOTAL = 6		

Transect Location (River Mile)	No. of Core Sampling Sites[1]	No. of Layers Sampled[1]	No. of Sites Sampled in Duplicate
	BEAR CREEK		
0.55[2]	1	4	0
2.80[1]	1	1	0
2.75[2]	1	3	0
7.40[2]	1	4	0
TOTALS	4	12	0
	WHITE OAK CREEK		
0.18[2] (instream)	1	4	0
0.38[2] (instream)	1	4	0
0.51[2] (instream)	1	4	1
0.55[2] (instream)	1	4	0
	—	—	—
TOTALS	4	16	1

[1]Columns entitled No. of Core Sampling Sites and No. of Layers Sampled do not include duplicate cores and layers.

[2]Sites at which cores for radiological analyses were collected.

TABLE 3

INSTREAM CONTAMINANT STUDY - TASK 2
MERCURY CONTAMINATED SEDIMENT - CORE LABORATORY ANALYSES - EAST FORK POPLAR CREEK, BEAR CREEK, AND WHITE OAK CREEK

Parameter	Analyses	No. of Sediment Layers Analyzed[1]			No. of Layers Analyzed as Lab Duplicates[2]		
		Preliminary Survey	Intensive Survey	Contaminant Bdy. Survey	Preliminary Survey	Intensive Survey	Contaminant Bdy. Survey
		EAST FORK POPLAR CREEK					
Mercury	Single determinations for fractions <500 and <62 micrometers	49	0	0	0	0	0
	Triplicate determinations for fractions <500 and <62 micrometers	28	0	0	8	0	0
	Single determinations for fractions <0.25 in. and <2,000, <500, <125, and <62 micrometers and triplicate determinations on the total sample	0	5	0	0	0	0
	Single determinations for fractions <0.25 in., and <2,000, <500, <125, and <62 micrometers	0	51	0	0	3	0
	Single determinations for fraction <500 micrometers	0	106	95	0	8	0
	TOTALS	77	162	95	8	11	0
Particle Size	Percent finer by weight than 2,000, 500, and 62 micrometers	77	0	0	8	0	0
	Percent finer by weight than 0.25 in. and 2,000, 500, 125, and 62 micrometers	0	20	0	0	0	0
	Percent finer by weight than 2,000, 500, 125, and 62 micrometers	0	77	0	0	7	0
	Percent finer by weight than 500 micrometers	0	65	87	0	5	0
	TOTALS	77	162	95	8	12	0
Moisture Content	% moisture	31	85	0	7	4	0
Specific Gravity	gram/gram	31	85	0	7	4	0
Radiological	Gross Alpha, Gross Beta, Sr 89 and 90, Uranium, Gamma Spectroscopy	9	0	0	0	0	0
	Transuranics[3] (Pu 238 and 239, Am 241, Cm 244)	6	0	0	0	0	0

TABLE 3 CONTINUED

INSTREAM CONTAMINANT STUDY - TASK 2
MERCURY CONTAMINATED SEDIMENT - CORE LABORATORY ANALYSES - EAST FORK POPLAR CREEK, BEAR CREEK, AND WHITE OAK CREEK

Parameter	Analyses	No. of Sediment[1] Layers Analyzed	No. of Sediment Layers Analyzed as Lab Duplicates[2]
		BEAR CREEK	
Mercury	Triplicate determinations for fraction finer than 500 micrometers and 62 micrometers	4	1
	Single determinations for fraction finer than 500 micrometers and 62 micrometers	9	0
	TOTALS	13	1
Particle Size	% finer than 2,000, 500, and 62 micrometers	12	1
Moisture Content	% moisture	4	1
Specific Gravity	gram/gram	4	1
Radiological Analyses	Gross Alpha, Gross Beta, Sr 89 and 90, Uranium, Gamma Spectroscopy	9	0
	Transuranics[3] (Pu 239 and 238, Am 241, Cm 244)	3	0
		WHITE OAK CREEK	
Mercury	Triplicate determinations for fraction finer than 500 micrometers and 62 micrometers	4	2
	Single determinations for fraction finer than 500 micrometers and 62 micrometers	12	0
	TOTALS	16	2
Particle Size Analyses	% finer than 2,000, 500, and 62 micrometers	16	2
Moisture Content	% moisture	4	2
Specific Gravity	gram/gram	4	2
Radiological Analyses	Gross Alpha, Gross Beta, Uranium, Sr 89 and 90, Gamma Spectroscopy	16	0
	Transuranic[3] (Pu 239 and 238, Am 241, Cm 244)	8	0

[1] No. of sample layers analyzed does not include field duplicate cores.

[2] Lab duplicates were prepared by splitting a single sample in the laboratory for duplicate analysis.

[3] Transuranic analyses performed by ORNL.

2.3 SURFACE LAYER, FINE-PARTICLE SEDIMENT SAMPLING

Surface layer samples were collected at 34 locations: sixteen on East Fork Poplar Creek; three on Bear Creek; four on lower White Oak Creek; three on Poplar Creek; four on the Clinch River in Watts Bar Reservoir; one in Melton Hill Reservoir (background sample); and three in Norris Reservoir (background samples). The locations are shown in Figure 1 for East Fork Poplar Creek and Bear Creek, Figure 2 for lower White Oak Creek and Poplar Creek, and Figure 3 for the Clinch River and Norris Reservoir. All samples were selectively collected in the streambed channel to obtain fine particle sediments believed to have a greater potential for indicating the presence of contaminants.

Samples were analyzed for mercury, priority pollutants (organics and metals), cyanide, phenols, PCBs, and radiological parameters. Table 4 indicates the sampling locations. Table 5 gives the type and number of laboratory analyses conducted.

2.4 CLINCH RIVER AND TENNESSEE RIVER CORE SAMPLING

Sediment cores were collected at eight locations on the Clinch River and at seven locations on the Tennessee River. Figures 3 and 4 show the core sampling locations. Table 7 indicates the sampling locations and the total number of sediment layers collected. Table 8 gives the type and number of laboratory analyses conducted (excluding field duplicates).

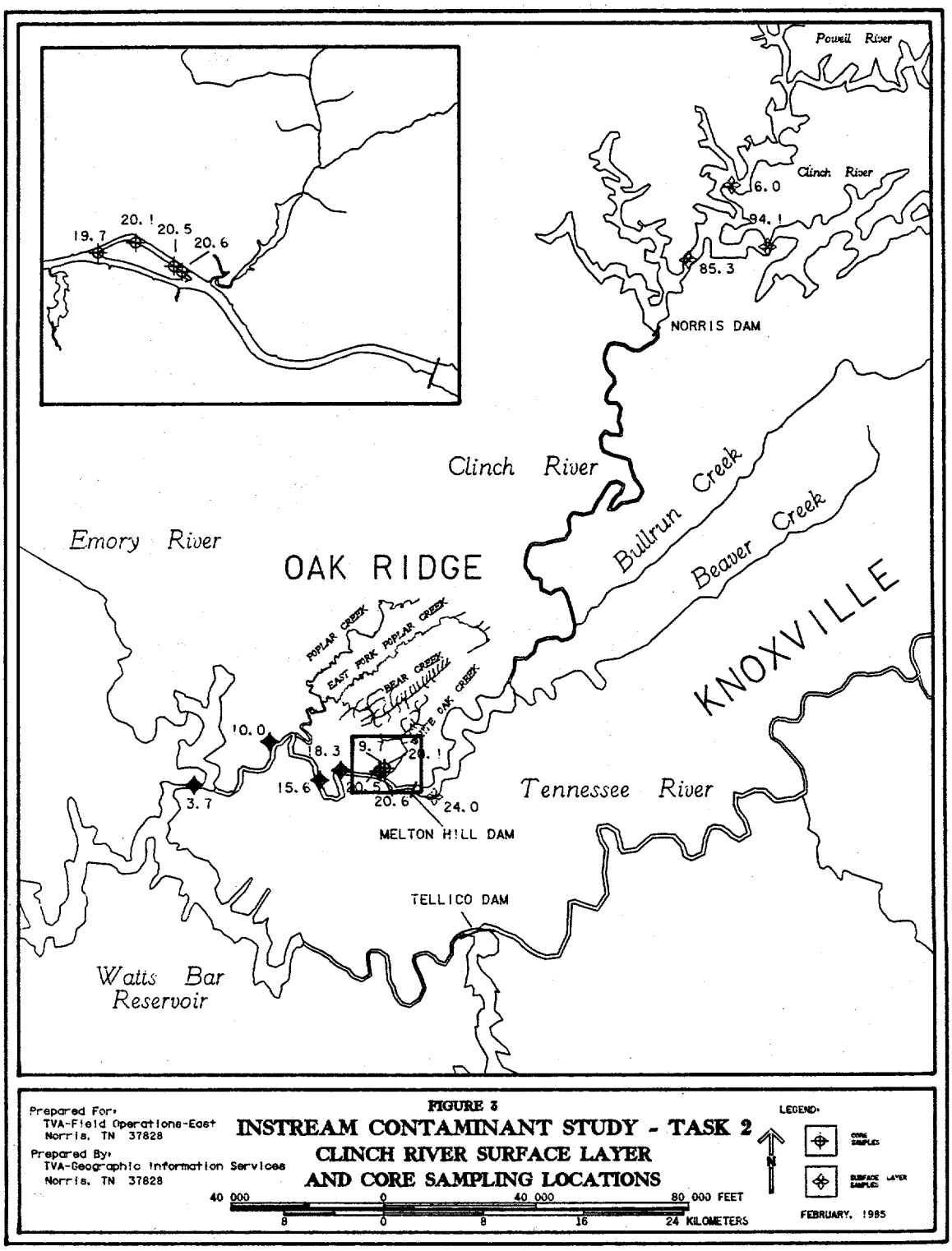
Powell River
Clinch River
6.0
94.1
85.3
NORRIS DAM
19.7
20.1
20.5
20.6
Clinch River
Bullrun Creek
Beaver Creek
Emory River
OAK RIDGE
KNOXVILLE
POPLAR CREEK
EAST FORK POPLAR CREEK
BEAR CREEK
WHITE OAK CREEK
10.0
18.3
9.7
20.1
15.6
20.5
20.6
24.0
3.7
Tennessee River
MELTON HILL DAM
TELLICO DAM
Watts Bar Reservoir
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FIGURE 3
INSTREAM CONTAMINANT STUDY - TASK 2
CLINCH RIVER SURFACE LAYER
AND CORE SAMPLING LOCATIONS
40 000 0 40 000 80 000 FEET
8 0 8 16 24 KILOMETERS
LEGEND:
N
FEBRUARY, 1985

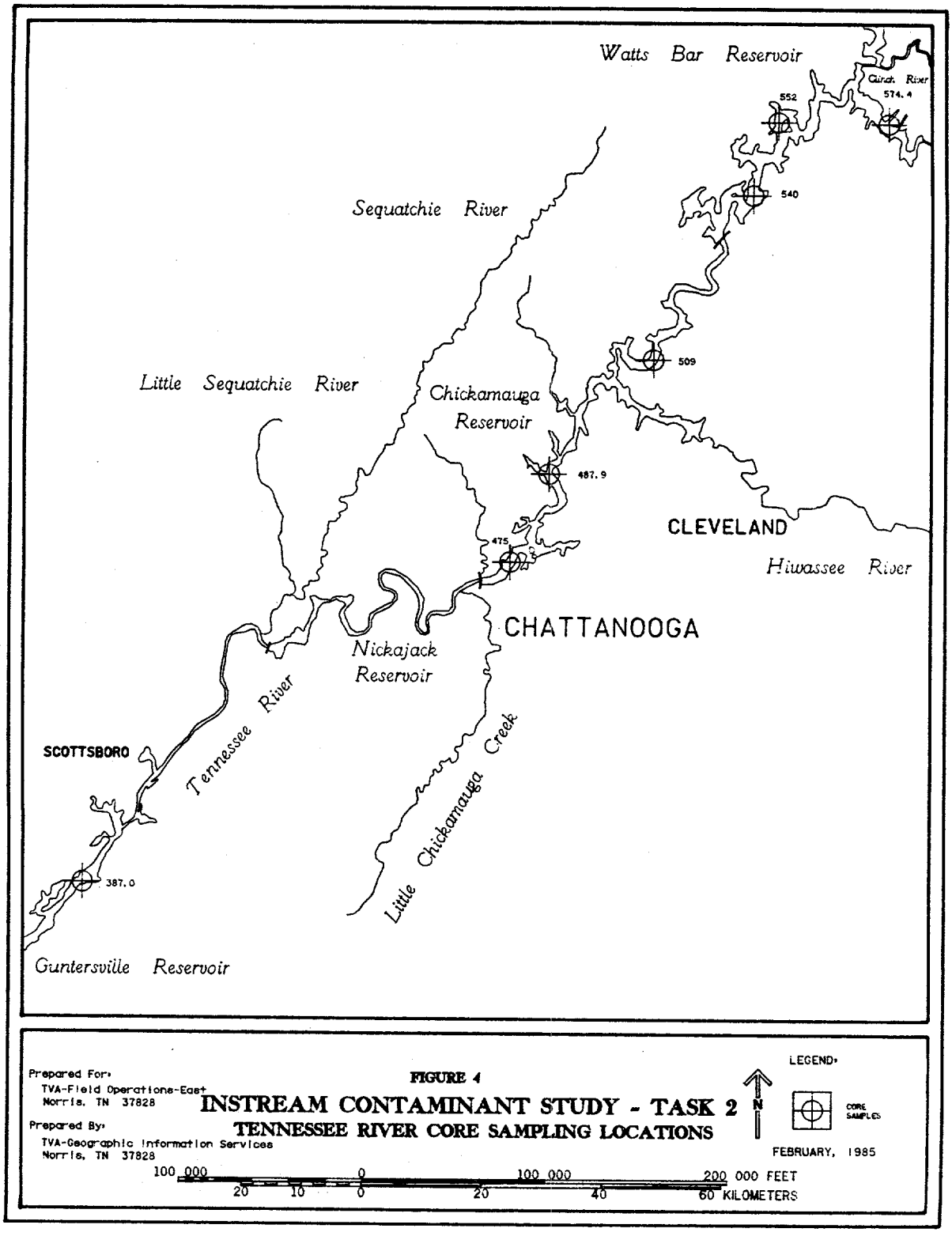
Watts Bar Reservoir
Clinch River
574.4
552
540
Sequatchie River
509
Little Sequatchie River
Chickamauga Reservoir
487.9
CLEVELAND
475
Hiwassee River
CHATTANOOGA
Nickajack Reservoir
Tennessee River
SCOTTSBORO
Little Chickamauga Creek
387.0
Guntersville Reservoir
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FIGURE 4
INSTREAM CONTAMINANT STUDY - TASK 2
TENNESSEE RIVER CORE SAMPLING LOCATIONS
LEGEND:
N
CORE SAMPLES
FEBRUARY, 1985
100 000 0 100 000 200 000 FEET
20 10 0 20 40 60 KILOMETERS

TABLE 4

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SEDIMENT SAMPLING - SAMPLE COLLECTION LOCATIONS

FINE SEDIMENT SAMPLING LOCATIONS

East Fork Poplar Creek	Bear Creek	Poplar Creek	White Oak Creek	Clinch River		Norris Reservoir
				Watts Bar	Melton Hill	
EFPCM 1.20	BCM 0.55	PCM 1.00	WOCM 0.18	CRM 3.70	CRM 24.00	CRM 85.30
2.36	2.80	3.80	0.38	10.00		94.10
3.50	7.40	6.80	0.51	15.60		
4.50			0.55	18.30		Powell River
5.74						Mile 6.0
6.72						
7.95						
9.21						
10.00						
11.30						
12.39						
12.89						
13.66						
13.71						
13.74						
14.36						

TABLE 5

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SEDIMENT SAMPLING - TYPE AND NUMBER OF ANALYSES

Parameter	Analyses	No. of Samples Analyzed[1]						
		East Fork[2,3] Poplar Creek	Bear[2] Creek	Poplar Creek	White Oak[2] Creek	Clinch River Watts Bar[3]	Clinch River Melton Hill	Norris Reservoir
Mercury	Analyzed for total sample	15	3	3	4	4	1	3
Particle Size	% finer than 0.5, 2, 8, 16, and 62 micrometers	13	2	3	4	4	1	3
	% finer than 0.5, 2, 8, 16, 62, 125, 500, and 2,000 micrometers	2	1	0	0	0	0	0
Volatile Residue	% solids	15	3	3	4	4	1	3
Moisture Content	% moisture	15	3	3	4	4	1	3
Specific Gravity	gram/gram	15	3	3	4	4	1	3
Cation Exchange Capacity	--	15	3	3	4	4	1	3
Cyanide	--	16	3	3	4	4	1	3
Phenol	--	16	3	3	4	4	1	3
Base/Neutral Priority Pollutants	See Table 6	16	3	3	4	4	1	0
Polychlorinated Biphenyls	See Table 6	16	3	3	4	4	1	3
Priority Pollutant Metals	See Table 6	16	3	3	4	4	1	3
Radiological Analyses	Gross Alpha, Gross Beta, Sr 89 and 90, Uranium, Gamma Spectroscopy	16	3	3	4	5	1	3
Radiological Transuranic Analyses[4]	Pu 238 and 239, Am 241, Cm 244	7	1	1	3	3	0	1

[1] No. of analyses does not include analyses of duplicate samples; no field duplicates of surface layer samples were collected.

[2] Laboratory duplicate analyses for all nonradiological parameters were performed on three samples from East Fork Poplar Creek, one from Bear Creek, and one from White Oak Creek.

[3] Laboratory duplicate analyses for all radiological parameters except transuranics were performed on three samples from East Fork Poplar Creek and one sample from the Clinch River (Watts Bar).

[4] Transuranic analyses were performed by ORNL.

TABLE 6

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SAMPLING - ORGANIC PRIORITY
POLLUTANT PARAMETERS ANALYZED

BASE/NEUTRAL COMPOUNDS	POLYCHLORINATED BIPHENYLS (PCBs)
Acenapthalene	Arochlor 1260
Acenapthene	Arochlor 1254
Anthracene	Arochlor 1221
Benzo(B)Fluoranthene	Arochlor 1232
Benzo(K)Fluoranthene	Arochlor 1248
Benzo(A)Pyrene	Arochlor 1242
Bis(2-chloroethyl)ether	Arochlor 1016
Bis(2-chloroethoxy)methane	
Bis(2-chloroisopropyl)ether	
N-butyl benzyl phthalate	
Chrysene	
Diethyl phthalate	
Dimethyl phthalate	
1,2-Diphenylhydrazine	
Fluoranthene	
Fluorene	
Hexachlorocyclopentadiene	
Hexachloroethane	
Indeno(1,2,3-CD)pyrene	
Isophorone	
N-nitrosodi-N-propylamine	
N-nitrosodiphenylamine	
N-nitrosodimethylamine	
Napthalene	
Nitrobenzene	
Phenanthrene	
Pyrene	
Benzo(GHl)perylene	
Benzo(A)anthracene	
1,2-dichlorobenzene	
1,2,4-trichlorobenzene	
1,2,5,6-dibenzanthracene	
1,3-dichlorobenzene	
1,4-dichlorobenzene	
2-chloronapthalene	
Di-n-octyl phthalate	
2,4-dinitrotoluene	
2,6-dinitrotoluene	
3,3'-dichlorobenzidine	
4-bromophenyl phenyl ether	
4-chlorophenyl phenyl ether	
Di-n-butyl phthalate	
Benzidine	
Bis(2-ethylhexyl)phthalate	
Hexachlorobenzene	
Hexachlorobutadiene	

TABLE 7

INSTREAM CONTAMINANT STUDY - TASK 2
CLINCH RIVER AND TENNESSEE RIVER CORE SAMPLING -
CORE SAMPLING LOCATIONS

Location	Description	Total No. Layers[1] Collected
	CLINCH RIVER	
CRM 3.7	Watts Bar Reservoir	9
CRM 10.0	Watts Bar Reservoir	6
CRM 15.6	Watts Bar Reservoir	6
CRM 18.3[2]	Watts Bar Reservoir, on Grubb Island	9
CRM 19.7[2]	Watts Bar Reservoir, on Jones Island	9
CRM 20.1	Watts Bar Reservoir, on Jones Island	9
CRM 20.5	Watts Bar Reservoir, on Jones Island	9
CRM 20.6	Watts Bar Reservoir, on Jones Island	1
	TOTAL	58
	TENNESSEE RIVER	
TRM 387.0	Guntersville Reservoir	25
TRM 475.0	Chickamauga Reservoir	25
TRM 487.9	Chickamauga Reservoir	24
TRM 509.0	Chickamauga Reservoir	21
TRM 540.0	Watts Bar Reservoir	31
TRM 552.0	Watts Bar Reservoir	30
TRM 574.4	Watts Bar Reservoir (Background Sample)	29
	TOTAL	185

[1]Total No. of Layers does not include field duplicates.

[2]Duplicate core collected for mercury and particle size analyses.

TABLE 8

INSTREAM CONTAMINANT STUDY - TASK 2
CLINCH RIVER AND TENNESSEE RIVER CORE SAMPLING - TYPE AND NUMBER OF ANALYSES

Parameter	Analyses	No. of Layers Analyzed	No. of Layers[1] Analyzed as Lab Duplicates	No. of Composite Samples Analyzed
		CLINCH RIVER		
Mercury	Triplicate determinations for fractions less than 500 and 62 micrometers	7	3	0
	Single determinations for fractions less than 500 and 62 micrometers	21	0	0
Particle Size	% finer than 2,000, 500, and 62 micrometers	28	3	0
Radiological Analyses	Gross Alpha, Gross Beta	30	1	0
	Sr 89 and 90, Uranium, Gamma Spectroscopy	1	0	7
	Transuranics[2] (Pu 238 and 239, Am 241, Cm 244)	0	0	4
		TENNESSEE RIVER		
Mercury	Analyzed for total sample	109	8	0
Particle Size	% finer than 2,000, 500, 125, and 62 micrometers	28	5	0
PCB	PCB 1221, 1232, 1242, 1248, 1254, 1260, and 1016	48	3	0
Chromium	--	48	3	0

[1]Number of layers analyzed does not include analyses of field duplicates.

[2]Transuranic analyses were performed by ORNL.

[3]Laboratory duplicates are single samples split by the laboratory for duplicate analyses.

3.0 PROCEDURES AND METHODOLOGY

3.1 AREAL EXTENT - FLOODPLAIN MAPPING

Flood elevations for the Clinch River were tabulated from existing TVA data. On Poplar Creek and East Fork Poplar Creek, existing HEC-2 models were adjusted using new survey data (i.e., new natural ground cross sections, see Section 2.1) to extend the reach limits to areas not previously modeled. Flood elevations were then computed using floodflows corresponding to the maximum flood of record (determined from USGS records) since 1940, the approximate beginning of DOE operations. Bear Creek flood elevations were determined using a short-reach HEC-2 model adjusted with new survey data (natural ground cross sections and culvert and bridge measurements). The floodflow corresponding to the maximum event of record during DOE operations was also used for the Bear Creek model. Flood elevations between established cross sections were estimated based on information from USGS topographic maps.

3.2 FIELD PROCEDURES

All sediment samples were obtained in accordance with applicable sample collection, handling, and preservation procedures as described in the TVA Field Operations Natural Resource Engineering Procedures Manual (3).

3.2.1 MERCURY CONTAMINATED SEDIMENT SAMPLING

Sediment samples to define the extent of mercury contamination were collected in and along East Fork Poplar Creek, Bear Creek, and along lower White Oak Creek as described in Section 2.2.

Prior to sampling, available data and floodplain maps were reviewed. Since existing mercury data for Bear Creek and White Oak Creek showed little or no mercury contamination (2), sampling activities were directed primarily towards East Fork Poplar Creek, with only limited sampling in Bear Creek and lower White Oak Creek to confirm previous findings.

Four assumptions were made in selecting the core sampling locations on East Fork Poplar Creek. First, mercury contamination was assumed to be confined to the floodplain boundaries as delineated by the floodplain maps. Second, it was assumed that the floodplain could be divided into characteristic stream reaches according to floodplain widths, constant channel gradients, and contractions and expansions of the floodplain. Based upon this assumption, characteristic stream reaches were identified at approximate one-mile intervals along the length of the creek. Third, it was assumed that sediment deposition within a characteristic reach varied more along a transect, perpendicular to the channel, than longitudinally, parallel to the channel. Finally, historic sediment deposition was assumed to have been a function of streamflow, with floodplain sedimentation resulting from decreases in velocity as the flood water spread over the floodplain. Coarse sediment would be deposited in the area immediately adjacent to the stream channel and finer sediment would be transported farther out and deposited in layers over the floodplain. Thus, the most extensive deposits would occur in the wide and flat sections of the floodplain where lower velocities would exist during and/or after a flood event.

The initial core sampling survey on East Fork Poplar Creek was conducted from June 18-27 and involved 16 of the final 30 transects (Section 2.2). Samples were collected at one horizontal location along each transect (i.e., one position in the floodplain perpendicular to the channel), except at EFPCM 13.71 and 13.66 where previous sampling by ORNL had shown high levels of mercury contamination. At these locations cores were collected at seven locations along each transect. Sampling of the Bear Creek floodplain was conducted in conjunction with this initial survey of East Fork Poplar Creek except for the collection of cores for radiological analyses which was conducted on September 12.

Based on the laboratory analyses of the initial samples, 18 transects (including four of the previously sampled transects) were sampled in East Fork Poplar Creek on September 18-25. Cores were collected at several horizontal locations along each transect. Instream surface samples were also collected at each of the 18 transect locations and at East Fork Poplar Creek Mile 5.74.

After reviewing results of the second survey, a third survey was conducted on November 6-7 to further define horizontal and vertical boundaries of the mercury contamination.

Core samples from East Fork Poplar Creek and Bear Creek were collected using either a Wilco or Back-Saver core sampler. The Back-Saver was more

suitable for harder soils and received the greatest use. The Wilco sampler was used primarily for EFPCM 13.51 through 13.71. Surface sediment samples obtained from East Fork Poplar Creek were obtained using a metal hand scoop.

The criteria used to determine core depth was the penetration to a gray, Pliestocene clay which predated the operations at Y-12. Cesium counting by ORNL was also used in identifying the boundary between contaminated and uncontaminated sediment. After extrusion, core samples were fractioned into even layers and along obvious soil horizons. Soil characteristics useful in recognizing unique sediment layers were color, compaction, stratification, and texture. Each core was divided into vertical layers based on these characteristics and the total core depth. Each segment was placed in a plastic bag and shipped to the TVA Laboratory Branch in Chattanooga or to the TVA Western Area Radiological Laboratory (WARL) in Muscle Shoals.

Core samples from lower White Oak Creek were collected by boat at four instream locations where sediment deposition was believed to be greatest. The samples were collected by manually pushing plastic core liner tubes into the sediment, retracting the liners, and then extruding the core. The core was then segmented into four equal layers and each segment was placed in a plastic bag. Special precautions were followed in collecting, handling, and shipping White Oak Creek sediment samples. Authorized

sampling equipment was used and health physicists from TVA and ORNL evaluated personnel and samples immediately after collection. Packaging and transport procedures were in accordance with Department of Transportation regulations for the shipping of low level radioactive wastes. Samples were transported in an approved vehicle to WARL where the radiological health staff evaluated the samples and authorized further analyses. The samples for nonradiological analyses were then transported to the TVA Laboratory Branch in Chattanooga.

3.2.2 SURFACE LAYER, FINE-PARTICLE SEDIMENT SAMPLING

Surface layer samples (i.e., upper 10 to 15 cm of sediment) were collected instream from the channel bed of East Fork Poplar Creek, Bear Creek, Poplar Creek, White Oak Creek, the Clinch River (Watts Bar and Melton Hill Reservoirs), and Norris Reservoir. All samples were selectively collected to obtain the fine sediment size fractions.

Samples from East Fork Poplar Creek and Bear Creek were obtained using a metal hand scoop. Samples from the Clinch River, Norris Reservoir, and Poplar Creek were obtained by boat using a Ponar dredge sampler attached to a motor-driven winch. Samples from lower White Oak Creek were obtained by boat using a hand-operated Eckman dredge sampler. Following collection, the samples were placed in plastic bags or glass jars (base/neutral and PCB analyses) and shipped to the TVA Laboratory Branch in Chattanooga or to the TVA Western Area Radiological Laboratory (WARL)

in Muscle Shoals. Special precautions were followed in the collection, handling, and shipping of White Oak Creek sediment samples as described in Section 3.2.1.

3.2.3 CLINCH RIVER AND TENNESSEE RIVER CORE SAMPLING

Samples collected on Grubb Island and Jones Island were collected using the Back-Saver core sampler. All other sediment cores were collected from inundated areas of the Clinch River and Tennessee River by divers using a Wilco sampler. A depth recorder was used in locating areas of likely sediment deposition. The Wilco sampler was lowered by a motor-driven winch to within approximately 10 feet of the river bottom and released. At the Tennessee River sampling locations, divers also assisted in guiding and pushing the sampler into the bottom. After impaction, the winch retrieved the sampler and divers capped the end of the sampler barrel with a rubber stopper to reduce sediment loss.

Three cores were collected at each Clinch River sampling location. One core was segmented into four equal layers for mercury and other nonradiological analyses. The second core was segmented into approximate 15 cm layers for radiological analyses. Core segments were placed in plastic bags and shipped to the TVA Laboratory Branch in Chattanooga and TVA WARL in Muscle Shoals. The third core was left intact and sent to ORNL for archiving in refrigerated storage.

Four cores were collected at each Tennessee River sampling location. The first core was segmented into four equal layers for particle size analyses. The second core was segmented into approximately 15 cm intervals for PCB and chromium analyses. The third core was segmented into approximate 5 cm intervals for mercury analyses. The core segments for particle size and mercury analyses were placed in plastic bags while the segments for PCB and chromium analyses were placed in glass jars (to prevent interference of plasticizers in PCB analyses). The core segments were shipped to the TVA Laboratory Branch in Chattanooga. The fourth core was left intact and sent to ORNL for archiving in refrigerated storage.

3.3 LABORATORY PROCEDURES

3.3.1 SAMPLE COLLECTION, SHIPPING, AND RECEIVING

Samples were collected and shipped along with field data sheets to the TVA Laboratory Branch in Chattanooga or to the TVA Western Area Radiological Laboratory (WARL) in Muscle Shoals (Appendix V - Figure 1). Upon receipt in the laboratory, samples were inventoried, irregularities noted, and the samples logged into the computer system. Blind laboratory duplicates were prepared by splitting thoroughly homogenized samples. These split samples were also logged into the computer system.

3.3.2 LABORATORY ANALYSES AND DATA REPORTING

A flow chart showing laboratory and data reporting steps is given in Appendix V - Figure 2. Samples and blanks were analyzed in accordance

with standard TVA laboratory procedures (4). Specific references, type of analysis, and detection limits for the analytical procedures are listed in Appendix V. The Laboratory Branch Intralaboratory Quality Control Program was followed by analyzing approximately ten percent of the samples in duplicate and, when possible, spiking ten percent of the samples.

Results from accuracy and precision quality control samples were plotted on control charts. If a result was outside the control limits, the samples were resubmitted for analysis.

All analytical data were recorded in laboratory notebooks, calculations checked, analysis approved, and results forwarded to the Quality Assurance Coordinator (QAC). The QAC summarized the blind laboratory and field duplicates along with the reference samples. If the data indicated a problem, corrective actions were taken. If possible, the samples were resubmitted for analysis.

The QAC compared the blind laboratory duplicates with the field duplicates. If there was a significant difference between the laboratory and field variability, the QAC notified the Project Manager of homogeneity problems. The QAC also "flagged" all questionable data with appropriate qualifying remarks.

3.4 DATA STORAGE

The QAC forwarded the approved data to the Task Leader who prepared a report of results which was submitted to data processing. The data were keypunched, verified, and stored on the EPA-STORET data system. Completed printouts of data were forwarded to the responsible Task Leader who reviewed the printout for reasonableness and approved final printout of data.

3.5 QUALITY CONTROL

A complete discussion of the TVA Quality Assurance Program is given in Reference 5.

3.5.1 INTRALABORATORY CONTROL CHARTS

3.5.1.1 EVALUATION OF ACCURACY

Data for accuracy control charts were generated by analyzing actual samples spiked with known amounts of the analyte. The percent recovery was determined, and 100 percent was subtracted from the recovery to obtain the percent bias. Percent bias values were plotted on control charts that indicated upper and lower warning and control limits.

Warning and control limits for accuracy control charts were calculated from actual recovery data obtained from analysis of large batches of samples (nominally, at least 20 values). Using the individual percent

bias values, the mean ($\overline{x}$) and the standard deviation (SD) were calculated. Warning and control limits were established as $\overline{x} \pm 1$ SD and $\overline{x} \pm 2$ SD, respectively.

Two consecutive observations or repeated results outside the warning limits required an examination of the system to prevent it from going out of control. The analysis was judged "out of control" when any point fell outside the control limits. Standard policy was to reanalyze all samples determined during any period shown to be out-of-control.

3.5.1.2 EVALUATION OF PRECISION

Data for precision control charts were generated by analyzing actual samples in duplicate. The difference between the two values was multiplied by 0.89 to obtain the approximate standard deviation (4). The standard deviation multiplied by 100 divided by the mean of the duplicate values yielded the relative standard deviation in percent (percent RSD). The percent RSD values were plotted on control charts that indicate warning and control limits.

Warning and control limits for precision control charts were calculated from actual precision data obtained from analyses large batches of samples (nominally, at least 20 values). Using the individual relative standard deviation values, the mean ($\overline{x}$) and standard deviation (SD) were calculated. Warning and control limits were established as $\overline{x} + 1$ SD and $\overline{x} + 2$ SD, respectively.

Two consecutive observations or repeated results outside the warning limit required corrective action. The analysis was judged out-of-control when any value fell outside the control limits. Standard policy was to reanalyze all samples determined during a period shown to be out-of-control.

3.5.2 REFERENCE SAMPLES

Standard reference materials supplied by National Bureau of Standards (NBS), Eastman Kodak Company, and Environmental Protection Agency (EPA) were analyzed (when certified material was available) with each set of Oak Ridge samples. These results were used to provide a measure of the accuracy of the overall data set.

The recovery data for each parameter was summarized by calculating the mean percent recovery and the standard deviation. An estimate of the reliability of mean percent recovery values was determined by calculating the 95 percent confidence interval of the mean. The equation for this calculation is $\bar{X} \pm t(SD/n)$ where t is the students t value, SD is the standard deviation, and n the number of reference samples determined. This interval means that there is a 95 percent chance the true percent recovery value lies within the values. If there is no statistically significant bias in the analytical procedure, the 95 percent confidence interval of the mean should encompass 100 percent recovery.

TVA's Western Area Radiological Laboratory (WARL) participates in twelve or more of the laboratory intercomparison studies conducted by EPA's Las Vegas laboratory. The results from this intercomparison are presented in the annual environmental operating reports for TVA's nuclear power plants. WARL also analyzes crosscheck samples produced by TVA's laboratory quality control program for nuclear radiochemical laboratories.

3.5.3 BLIND DUPLICATE SAMPLES

3.5.3.1 BLIND FIELD DUPLICATES

Duplicate samples were periodically collected and shipped to the Laboratory Branch or WARL. These samples were inserted blind into the analytical stream along with the other samples. The relative standard deviation was calculated from the nonradiological duplicate data as described in Section 3.5.1.2.

3.5.3.2 BLIND LABORATORY DUPLICATES

The Quality Assurance Coordinator prepared a second aliquot from an original sample by splitting the sample after it had been thoroughly mixed. These samples were also inserted blind into the analytical stream. The relative standard deviation was calculated from these duplicate data as described in Section 3.5.1.2.

The WARL routinely checks its various radiochemical procedures by analyzing a series of quality control samples comprising approximately 10 percent of its sample load. These quality control checks include blind laboratory duplicates, blanks, backgrounds, counting standards, work station routine spikes, blind spikes, and in-house crosschecks.

3.5.4 EPA SPLIT SAMPLES

Approximately five percent of all sediment samples were thoroughly homogenized and a representative aliquot sent to the EPA Region IV Laboratory and/or the EPA Eastern Environmental Radiation Facility (EERL) for the analysis of the same parameters analyzed on the original sample. EPA split samples were submitted incrementally throughout the project to ensure early detection and correction of any analytical problem. Interlaboratory split data were analyzed using percent relative error to determine if bias existed between the TVA and EPA laboratories. This procedure is explained as follows:

Percent relative error is defined as the difference between two replicate samples divided by the mean of the samples expressed as percent. It is calculated as follows:

$$\% \text{ Relative Error} = \frac{\{\text{EPA Result} - \text{TVA Result}\}}{\{\text{EPA Result} + \text{TVA Result}\}} \times 200$$

Percent relative error can vary only between -200 and +200. A helpful way of conceptualizing relative error is to consider its relationship to the ratio of the two laboratories. This relationship can be calculated as follows:

$$\text{Ratio} \quad \frac{\text{EPA Result}}{\text{TVA Result}} = \frac{\{200 + \% \text{ relative error}\}}{\{200 - \% \text{ relative error}\}}$$

Representative values are as follows:

Ratio (EPA Result / TVA Result)	% Relative Error	Ratio (EPA Result / TVA Result)	% Relative Error
0	-200	∞	200
0.01	-196	100	196
0.10	-164	10	164
0.20	-138	5	133
0.33	-100	3	100
0.50	- 67	2	67
0.67	- 40	1.5	40
0.83	- 18	1.2	18

4.0 RESULTS AND DISCUSSION

4.1 AREAL EXTENT - FLOODPLAIN MAPPING

The floodplains of the Clinch River (mile 0 to Melton Hill Dam at mile 23.10) and Poplar Creek (mile 0 to 5.63) were defined by tabulating flood elevations at existing and newly surveyed cross section locations. On East Fork Poplar Creek and Bear Creek, flood elevations were tabulated and the floodplains depicted on USGS topographic maps at a scale of 1" = 400' (Section 2.1). Reproducible originals of the USGS topographic maps have been provided to the Department of Energy.

4.2 MERCURY CONTAMINATED SEDIMENTS

4.2.1 MERCURY

4.2.1.1 EAST FORK POPLAR CREEK

The East Fork Poplar Creek valley is characterized by alluvial deposits, vertical accretion, and natural levees. The velocity of flood waters abruptly decreases outside of the stream channel, affecting the pattern of sediment deposition. The thickest and coarsest accumulations form as low ridges or levees immediately bordering the channel. The more extensive deposits appear to occur along the low and flat parts of the floodplain. These deposits reflect the settling of part of the suspended load carried by past flood waters. The finer sediment appears to be carried farther from the channel and is deposited in a thin layer over the entire floodplain. Backland deposits consisting of smaller particle sizes were observed in the lowest parts of the floodplain where the flood waters pond behind levees.

4.2.1.1.1 SUMMARY OF RESULTS

A complete listing of the mercury contaminated sediment data from East Fork Poplar Creek is given in Appendix I - Table 2. Table 1 of Appendix I summarizes the mercury and particle size data for the sediment fractions finer than 500 and 62 µm. Figures 1 through 30 in Appendix I show the ground surface elevations (looking downstream) and the mercury

concentration of samples collected along each transect. Ground elevations were taken from cross section surveys by TVA during August 1959, October 1967, April 1970, July 1980, May 1984, and February 1985. Surveys taken prior to 1984 were collected by TVA for the Oak Ridge Regional Planning Commission (6, 7) and for the Federal Emergency Management Agency (8). Survey data in 1984 and 1985 were obtained as part of the Instream Contaminant Study.

The mercury concentration of each core layer is given in Figures 1-30 of Appendix I as a histogram at each sampling location. Approximately 80 percent of all cores penetrated to the underlying "uncontaminated" sediment as defined by mercury concentrations less than 5.0 mg/kg. All mercury versus depth histograms are plotted on the same scale, and are comparable from figure to figure. The mercury concentration is represented by the horizontal length of each bar. The vertical length represents the actual length of the core layer. Typically, a core was divided into 3-9 inch layers and an average mercury concentration determined for each layer.

Mercury values reported to the left of each histogram bar represent the concentration in milligrams of mercury per kilogram dry weight of sample for the fraction of the sample finer than 500 μm, except for the instream samples from East Fork Poplar Creek Miles 1.20, 4.50, 9.21, 10.00, 11.30, 12.89, 13.66, 13.71, 13.74, and 14.36 where concentrations

are reported for the total sample(i.e., less than 1/4 inch). For the samples reported as less than 500 μm, the particle size distribution data has a mean of 85.5 and a standard deviation of 20.9 for the percent of the total sample less than 500 μm.

Three types of duplicate samples and analyses were used: samples analyzed in triplicate in the laboratory; field duplicates taken at the same position on the transect on the same day; and duplicates taken at the same position on the transect on different dates, September 21 and November 7. The duplicates were used to estimate sample variability (Section 4.5). Where field duplicates were collected, and/or laboratory duplicates analyzed, the mercury concentrations given in Figures 1-30 of Appendix I are an average of the duplicate values. Where field duplicates were collected and the core layers divided into different depths, results from the deepest core are shown in the figures.

The mercury concentration of field duplicate cores often varied substantially at the same depth. For example, the core collected at horizontal position +122.5 at mile 4.52 had a mercury concentration of 69 mg/kg, but a the duplicate core at the same layer showed a concentration of less than 0.5 mg/kg. These results suggest substantial variability (small scale heterogeneity) within the sediment/floodplain environment.

Table 9 gives the transect locations, maximum flood of record elevations, and a summary of the sediment mercury and particle size data for the 17 representative stream reaches used in analyzing East Fork Poplar Creek. The highest mercury concentrations in the sediment occurred in the upper reaches with an obvious decreasing trend moving downstream. Mean reach concentrations ranged from 281 mg/kg between miles 10.15-11.50 to 18 mg/kg between miles 2.0-2.7.

Currently, there are no generally accepted standards or criteria for mercury in sediment. However, based on previous TVA data, values exceeding 1-2 mg/kg may suggest a source of mercury contamination. Past studies of East Fork Poplar Creek sediment report a maximum concentration of 480 mg/kg (9). The highest concentrations found during this study for the <500 μm particle size class were 1800 mg/kg at EFPC Mile 13.71 and 1300 mg/kg at EFPC Mile 10.9. These higher concentrations may be due to the fact that in this study sediment cores were discretely analyzed in layers isolating the higher mercury levels. Past methods of homogenizing the entire core prior to analysis reflect average mercury concentrations over the entire core depth.

The highest concentrations of mercury were frequently found below the surface layer. Substantial variation in the data was also observed as indicated by the standard deviation. However, since most statistical

TABLE 9

INSTREAM CONTAMINANT STUDY - TASK 2
SUMMARY OF TRANSECT DATA[1]
EAST FORK POPLAR CREEK

Stream Reach (Miles)	Transect Location(s) (Mile)	Maximum Flood Elevation (Feet MSL)	Particle Size[2] <500 µm (%)		Mercury Concentration[2] (mg/kg dry weight <500 µm)	
			Mean	Std. Deviation	Mean	Std. Deviation
0.00-1.29	0.23 1.20*	754.2 756.1	90.2	12.6	27.1	24.7
1.29-2.00	1.35*	756.4	96.9	4.8	53.4	57.5
2.00-2.70	2.36*	758.8	82.1	19.1	17.8	10.0
2.70-3.60	2.85* 3.50	762.0 771.1	89.5	16.3	31.1	20.3
3.60-4.80	4.50 4.52*	776.9 777.0	91.2	12.6	33.1	15.4
4.80-6.10	4.92* 5.74*	780.8 786.8	87.0	16.6	21.3	11.0
6.10-6.89	6.72*	793.6	92.3	10.4	84.9	103.8
6.89-7.95	7.05* 7.95	797.7 809.5	84.2	16.7	34.3	29.8
7.95-8.45	8.12	810.8	93.6	9.7	60.5	52.1
8.45-9.45	8.70* 9.21*	814.9 819.8	88.9	12.5	50.3	34.7
9.45-10.15	9.74* 10.00* 10.05*	824.0 827.6 831.2	81.5	26.0	94.1	81.7
10.15-11.50	10.90* 11.33*	837.9 840.8	93.7	6.9	281.2	382.6
11.50-12.12	12.06*	845.1	79.2	39.3	66.9	61.0
12.12-12.89	12.89*	853.2	79.7	14.5	42.8	20.6
12.89-13.27	13.00	855.8	85.3	22.6	60.8	60.8
13.27-13.85	13.55* 13.66 13.71*	863.8 866.5 867.9	90.8	9.6	228.3	387.5
13.85-14.40	14.02*	880.4	91.3	6.9	79.7	60.5
OVERALL MEAN AND STANDARD DEVIATION			90.2	13.5	114.4	231.8

[1]Mean and standard deviation for all sediment samples with a total mercury concentration equal to or greater than 5.0 mg/kg. Asterisks (*) indicate stream miles where cross sections were surveyed. The remaining cross section profiles were taken from the nearest previously surveyed cross section.

[2]Mean and standard deviation given for entire reach, rather than individual transects.

techniques assume random sampling and since site selection in this case was made in a nonrandom manner, statistical inferences must be made with caution.

Decreased mean concentrations were observed between miles 11.50-13.27, where alterations to the floodplain and channel are known to have occurred. Increased mean concentrations were found between miles 6.10-6.89, downstream of the municipal sewage treatment plant (located at approximate river mile 8.3), and between miles 1.29-2.00, near the mouth of East Fork Poplar Creek. A large sludge blanket was observed at EFPC Mile 7.95 (2-3 feet deep).

4.2.1.1.2 PRELIMINARY SEDIMENT VOLUME ESTIMATE

A preliminary estimate of the quantity of mercury contaminated sediment in East Fork Poplar Creek was made as follows.

Equation 1: $d = \frac{A_x}{W_x}$ $\frac{dl}{l}$

Equation 2: $V = dfA_s = \frac{A_x}{W_x}\frac{W_x}{W_s} A_s = \frac{A_x A_s}{W_s}$

d = mean depth of contaminated sediment
A_x = cross sectional area of transect in square feet
W_x = width or horizontal extent of contaminated floodplain in feet
V = contaminated sediment volume of transect reach in cubic feet
f = ratio of contaminated sediment width to floodplain width at each transect
A_s = surface area of transect reach in square feet as planimetered from floodplain maps
W_s = width or horizontal extent of floodplain of record in feet

A sediment mercury concentration of 5.0 mg/kg was assumed to be the lower limit of contamination. Although past remedial actions at Oak Ridge have not involved concentrations below 10.0 mg/kg, the use of 5.0 mg/kg as a lower limit allowed greater use of the available data and more closely approximated true background levels.

The surface profile and mercury core data were used to determine the cross sectional area of mercury contaminated sediment for each representative transect. The floodplain width at each transect and the floodplain surface area for each reach were obtained from results of the floodplain mapping. When more than one transect was obtained per stream reach, the average cross sectional area and floodplain width were used. Table 10 summarizes these parameters for each reach. The results indicate an estimated 15 million cubic feet of sediment within the East Fork Poplar Creek floodplain with a total mercury concentration equal to or exceeding 5.0 mg/kg. The mean mercury concentration of all core samples used in making this estimate was 114 mg/kg (Table 9).

An estimate of the total weight of mercury in the >5.0 mg/kg sediments of East Fork Poplar Creek is given in Table 11, based on a specific sediment weight of 95 pounds per cubic feet and the mean mercury concentration for each reach. The estimate of 157,000 pounds of mercury represents approximately two-thirds of the estimated 239,000 pounds of mercury lost to East Fork Poplar Creek between 1950 and 1983 (9).

TABLE 10

INSTREAM CONTAMINANT STUDY - TASK 2
PRELIMINARY SEDIMENT VOLUME ESTIMATES[1]
EAST FORK POPLAR CREEK

Stream Reach (Miles)	Cross Sectional Area of Contamination[2] (Square Feet)	Mean Depth of Contaminated Sediment (Feet)	Floodplain Area (Sq. Ft. x 10^6)	Floodplain Width (Feet)	Estimated Volume of Contaminated Sediment (Cu. Ft. x 10^6)
0.00-1.29	60.00	0.43	2.587	508	0.306
1.29-2.00	364.33	1.18	2.511	350	2.614
2.00-2.70	183.15	0.51	0.982	535	0.336
2.70-3.60	83.12	0.53	1.527	223	0.571
3.60-4.80	113.12	0.81	1.315	560	0.266
4.80-6.10	147.39	0.31	2.524	478	0.778
6.10-6.89	521.63	1.53	1.420	540	1.371
6.89-7.95	118.34	0.86	2.070	275	0.891
7.95-8.45	153.53	0.96	0.847	205	0.634
8.45-9.45	224.69	0.89	1.490	370	0.905
9.45-10.15	304.62	0.80	1.674	467	1.092
10.15-11.50	533.29	1.27	2.364	498	2.532
11.50-12.12	47.46	0.61	1.859	360	0.245
12.12-12.89	83.13	0.82	1.200	550	0.181
12.89-13.27	454.28	0.88	0.743	485	0.696
13.27-13.85	609.28	1.30	1.229	512	1.463
13.85-14.40	63.72	0.56	0.194	130	0.095
MEAN/TOTAL	239.12	0.84	26.536	414.5	14.976

[1]Estimated volume of sediment with a mercury concentration equal to or exceeding 5.0 mg/kg.

[2]Mean cross sectional area of contamination at core transects within each reach.

TABLE 11

INSTREAM CONTAMINANT STUDY - TASK 2
ESTIMATED SEDIMENT AND MERCURY QUANTITIES[1]
EAST FORK POPLAR CREEK

Stream Reach (Miles)	Mean Mercury Concentration (mg/kg)	Estimated Volume of Contaminated Sediment (Cu. Ft. x 10^6)	Estimated Weight of Contaminated Sediment[2] (Tons x 10^3)	Estimated Weight of Mercury in Sediment (Pounds)
0.00-1.29	27.1	0.306	14.53	790
1.29-2.00	53.4	2.614	124.16	13.250
2.00-2.70	17.8	0.336	15.96	570
2.70-3.60	31.1	0.571	27.10	1,680
3.60-4.80	33.1	0.266	12.62	840
4.80-6.10	21.3	0.778	36.97	1,580
6.10-6.89	84.9	1.371	65.13	11,600
6.89-7.95	34.3	0.891	42.31	2,900
7.95-8.45	60.5	0.634	30.13	3,650
8.45-9.45	50.3	0.905	42.97	4,320
9.45-10.15	94.1	1.092	51.88	9,760
10.15-11.50	281.2	2.532	120.27	67,630
11.50-12.12	66.9	0.245	11.64	1,560
12.12-12.89	42.8	0.181	8.61	740
12.89-13.27	60.8	0.696	33.06	4,020
13.27-13.85	228.3	1.463	69.49	31,730
13.85-14.40	79.7	0.095	4.51	720
TOTALS		14.976	711.34	157,340

[1]Quantities for sediment within the East Fork Poplar Creek floodplain that has a mercury concentration equal to or exceeding 5.0 mg/kg dry weight in the <500 µg fraction.

[2]Based on a specific weight of 95 pounds per cubic feet (11) and mean mercury concentration for the reach.

These estimates of the sediment volume and pounds of mercury within the floodplain of East Fork Poplar Creek represent an approximation of the total quantities involved. Although they are believed to be reasonable estimates, uncertainty arises not only from sampling and analytical variability, but also from variability in the distribution of mercury within the floodplain, from extrapolation of the data between transects and core sampling locations, and from the assumptions used in analyzing the data.

4.2.1.2 BEAR CREEK AND WHITE OAK CREEK

Limited sediment sampling was performed on Bear Creek and lower White Oak Creek, since previous studies suggest that these areas were not heavily contaminated with mercury (10). A summary of the data collected during this study are given in Table 12. Mercury concentrations in the Bear Creek floodplain were at background levels (0.2 mg/kg) except at mile 7.4 where a maximum concentration of 3.9 mg/kg was reported in one surface layer sample. Although this concentration is above background levels, it is substantially less than mercury concentrations reported in East Fork Poplar Creek. The lower White Oak Creek mercury concentrations were elevated in both the core and surface layer sediment samples.

4.2.2 RADIOLOGICAL ANALYSES

The results of radiological analyses are presented in Appendix I - Table 2. Table 13 summarizes the maximum concentrations of significant

TABLE 12

INSTREAM CONTAMINANT STUDY - TASK 2
SUMMARY OF BEAR CREEK AND WHITE OAK CREEK MERCURY CONCENTRATIONS

Location	Mile	Recent Concentration (<500 µm) (mg/kg)	Highest Concentration (<500 µm) (mg/kg)	Sediment Covering Highest Concentration (inches)	Core[2] Penetrated to Background
Bear Creek	7.4	3.9	3.9	None	Yes
	2.8	0.3	0.3	None	Yes
	0.65	0.2	0.3	18	Yes
White Oak Creek	0.55	2.5	2.5	None	Yes
	0.51	5.6	18.0	10	No
	0.38	10.0	44.0	11	No
	0.18	0.2	12.0	18	No

[1]Depth of sediment covering layer with highest mercury concentration.

[2]Background concentration is assumed to be 0.2 mg/kg; see Table 16.

TABLE 13

INSTREAM CONTAMINANT STUDY - TASK 2
MERCURY CONTAMINATED SEDIMENT - MAXIMUM CONCENTRATIONS REPORTED FOR SIGNIFICANT RADIOISOTOPES IN CORE SAMPLES (All concentrations are pCi/g, dry weight)[1]

	East Fork Poplar Creek	Bear Creek	White Oak Creek	Comparison Data: Tennessee River[2]	Comparison Data: Clinch River[3]	Comparison Data: Clinch River[4]
ANALYSIS/ISOTOPE						
Gross Alpha	40	7	4	15	6.9	14
Gross Beta	140	179	18,100	65	55	111
Uranium	73	167	18	--[5]	--[5]	5.1
Sr-89	.5	.5	12	14	2.8	3
Sr-90	.2	.2	563	.6	6.6	.1
GAMMA SPECTRAL ANALYSIS[6]						
Co-60	.4	-	437	.6	8.2	1.6
Cs-134	.1	-	1.7	.13	-	-
Cs-137	2.7	.5	46,900	5.5	370	42
K-40	21	22	25	27	60	44
Ra-226	-	1.2	.7	2.3	-	.9
Th-234	29	115	2	-	-	4
Eu-152	-	-	8.9	-	-	-
Eu-154	-	-	14	-	-	-
Am-241	-	-	73	-	-	-
Ac-228	-	1.2	.7	2.7	-	1.5
Pa-234m	41	181	-	4.6	-	-
U-235	1.7	3.8	-	-	-	-
TRANSURANICS						
Pu-239	.07	.002	2.6	-[5]	-[5]	.10
Pu-238	.10	<.001	.49	-[5]	-[5]	.01
Am-241	.06	.015	14.3	-[5]	-[5]	.30
Cm-244	.01	.005	12.4	-[5]	-[5]	.05

[1] Uranium reported in units of µg/g, dry weight.
[2] Maximum concentrations reported by TVA in surface sediment samples collected from the Tennessee River from 1981-83.
[3] Maximum concentrations reported by TVA in core sediment samples collected from the Clinch River from 1974-76.
[4] Maximum concentrations in Clinch River core samples collected during the Instream Contaminant Study - Task 2 (see section 2.4 and 3.4).
[5] Analysis not performed.
[6] Dash indicates isotope not identified in gamma spectral analysis.

NOTE: The lower limits of detection for all isotopes, as determined by the method developed by Pasternack and Harley, and described in HASL-300 and Nucl. Instr. Methods 91, 533-40 (1971), are typically 1 pCi/g, dry weight, or less.

radioisotopes for three core samples collected in the floodplain of East Fork Poplar Creek, three in the floodplain of Bear Creek, and four instream from lower White Oak Creek. Since no standards or guidelines exist for radionuclide concentrations in sediment, concentrations reported previously (1974-76 and 1981-83) by TVA from the analysis of samples from the Tennessee River and Clinch River are presented for comparison. Maximum radionuclide concentrations in core samples collected in the Clinch River as described in Sections 2.4, 3.4, and 4.4 are also presented for comparison.

Samples from East Fork Poplar Creek were found to contain little fission and activation product material (e.g., cesium 137 and cobalt 60). Cobalt 60 in East Fork Poplar Creek was less than the maximum reported in the Tennessee River and cesium 137 levels were all within the range reported for Tennessee River samples. Gross alpha and beta concentrations generally tended to increase with distance upstream, while cobalt 60 and cesium 137 levels generally decreased. Concentrations of uranium and radionuclides in the uranium decay series were higher in East Fork Poplar Creek than in the Clinch River by a factor of about 15. Transuranic isotopes exhibited concentrations significantly less than levels reported in the Clinch River.

Radioactivity patterns in Bear Creek were similar to those in East Fork Poplar Creek, except that concentration of uranium and uranium decay series radioisotopes were up to twice those in East Fork Poplar Creek, and cesium and cobalt concentrations were less. Cesium 137 and cobalt 60 concentrations were all less than the levels reported in the Tennessee River. Concentrations of transuranic isotopes were less than those reported in East Fork Poplar Creek.

As expected, radionuclide concentrations in lower White Oak Creek were higher than levels in other streams. Again, cesium 137 and cobalt 60 were the dominant isotopes, with significant concentrations of strontium 90 also reported. Uranium concentrations were less than in East Fork Poplar Creek and Bear Creek and were generally in the range of levels reported in the Clinch River, although two samples did exceed those levels by a factor of 2-3. Concentrations of transuranic isotopes were much higher than for the core samples collected in the Clinch River with concentrations of americium 241 and curium 244 as high as 14.3 pCi/gram and 12.4 pCi/gram, respectively.

4.3 SURFACE LAYER FINE-PARTICLE SEDIMENT

A total of 35 surface layer samples for multiparameter analyses were collected at 34 locations. Results are given in Appendix II. The following sections summarize the physical characteristics of the samples

(particle size, volatile residue, specific gravity, and cation exchange capacity) and the contaminant concentrations exceeding available standards, criteria, and/or background levels.

4.3.1 PHYSICAL CHARACTERISTICS

Table 14 summarizes physical characteristics of the surface layer samples. As might be expected, the greatest percentages of sediment fines were found at sampling locations in Norris Reservoir and Melton Hill Reservoir with up to 99.9 percent of some samples less than 62.5 μm. Mean percentages at other locations varied from 45.2 percent for East Fork Poplar Creek to 75.5 percent for Poplar Creek. Specific gravity results ranged from a mean value of 2.15 for Poplar Creek to a mean value of 2.49 for East Fork Poplar Creek possibly suggesting the presence of organic material. Mehta (11) reports that specific gravity of stream sediment is typically in the range of 2.6 to 2.7, unless organic materials are present. Percent volatile residue (also an indicator of organic content) varied from 2.3 percent for Clinch River Mile 10.0 (Watts Bar Reservoir) to 9.5 percent for Clinch River Mile 24.0 (Melton Hill Reservoir). Regression analyses of specific gravity and percent volatile residue data from all locations showed poor correlation ($r^2 = 0.38$). Regression analyses of the percent finer than 62.5 micrometers and specific gravity also showed poor correlation ($r^2 = 0.30$). A somewhat higher correlation was found between the percent finer than 62.5 micrometers and percent volatile residue ($r^2 = 0.53$).

TABLE 14

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SEDIMENT -
PHYSICAL CHARACTERISTICS OF SAMPLES

Stream	Mile	% Finer Than 62 µm	Specific Gravity	% Volatile Residue	Cation Exchange Capacity (meq/100 g)
East Fork Poplar Creek	1.20	64.0	2.50[1]	7.9[1]	12.0
	2.36	46.3	2.56	4.0	8.9
	3.50	56.6	2.07	6.0	12.0
	4.50	81.9	2.17	9.2	19.0
	5.74	64.6	2.56	4.8	9.7
	6.72	26.1	2.46	4.0	6.8
	7.95	41.0	2.54	6.0	8.3
	9.21	40.3	2.80	4.4	8.2
	10.00	42.2	2.90	4.8	7.7
	11.30	41.5	2.38	6.4	11.0
	12.39	53.0	2.59	6.4	12.0
	12.89	31.9	2.79[1]	4.5[1]	8.2
	13.66	23.8	2.35	5.6	7.7
	13.71	35.7	2.25	5.5	7.6
	13.74	28.5	2.64[1]	5.0[1]	7.8
	14.36	46.0	2.25	12.0	13.0
	MAX	81.9	2.90	12.0	19.0
	MIN	23.8	2.07	4.0	6.8
	MEAN	45.2	2.49	6.0	10.0
Bear Creek	0.55	45.5	2.32	3.2	6.0
	2.80	44.2	2.32[1]	5.9[1]	11.0
	7.40	27.2	2.42	6.1	8.4
	MAX	45.5	2.42	6.1	11.0
	MIN	27.2	2.32	3.2	6.0
	MEAN	40.0	2.35	5.1	8.5
Poplar Creek	1.00	97.1	2.29	9.3	5.9
	3.80	79.9	2.18	8.1	11.0
	6.80	49.6	1.97	4.0	8.4
	MAX	97.1	2.29	8.1	11.0
	MIN	49.6	1.97	4.0	5.9
	MEAN	75.5	2.15	7.13	8.4
White Oak Creek	0.30	10.6	2.52	4.9	9.5
	0.60	43.2	2.54	4.2	7.6
	1.00	68.1	2.32[1]	5.6[1]	9.7
	1.10	68.2	2.42	5.4	9.1
	MAX	68.2	2.54	5.6	9.7
	MIN	10.6	2.32	4.2	7.6
	MEAN	47.5	2.45	5.0	9.0
Clinch River (Watts Bar)	3.70	93.2	2.33	8.4	10.0
	10.00	17.7	2.52	2.3	3.4
	15.60	21.7	2.28	12.0	4.3
	18.30	81.9	2.38	7.1	8.8
	MAX	93.2	2.52	12.0	10.0
	MIN	17.7	2.28	2.3	3.4
	MEAN	53.6	2.38	7.5	6.6
Clinch River (Melton Hill)	24.00	97.7	2.16	9.5	33.0
Clinch River (Norris)	85.30	99.9	2.57	8.7	21.0
	94.10	99.9	2.34	9.3	23.0
	MAX	99.9	2.57	9.3	23.0
	MIN	99.9	2.34	8.7	21.0
	MEAN	99.9	2.45	9.0	22.0
Powell River (Norris)	6.00	99.5	2.43	8.6	16.0

[1]Value is mean of laboratory duplicate analyses.

Cation exchange capacity (CEC) varied from 3.4 meq/100 g for Clinch River Mile 10.0 (Watts Bar Reservoir) to a value of 33.0 meq/100 g for Clinch River Mile 24.0 in Melton Hill Reservoir.

4.3.2 METALS

Concentration values for mercury, arsenic, cadmium, chromium, nickel, silver, and zirconium are presented in Appendix II - Table 1. Detection limit values are followed by a "U" symbol indicating no evidence of the parameter below the detection limit, or by an "M" indicating evidence of parameter presence below the detection limit that could not be quantified. Table 15 summarizes the metals concentrations for the samples collected in each stream or reservoir. Table 16 summarizes available criteria and background levels for each metal. Concentrations in Melton Hill Reservoir and Norris Reservoir provide additional background data.

Several metals were measured at concentrations above available criteria and/or background levels (Table 16). For East Fork Poplar Creek, the mean mercury concentration of 40.0 mg/kg (Table 15) was substantially above background levels (0.1 to 0.3 mg/kg). Mean mercury concentrations in lower White Oak Creek and Poplar Creek of 3.3 and 3.4 mg/kg, respectively, were above background levels but were substantially less than concentrations in East Fork Poplar Creek. Mean mercury concentrations in Bear Creek and the Clinch River (Watts Bar Reservoir) were at or slightly

TABLE 15

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SEDIMENT - SUMMARY OF METAL CONCENTRATIONS

Parameter (ppm)[1]	East Fork Poplar Creek			Bear Creek			White Oak Creek			Poplar Creek		
	Max	Min (n=16)	Mean	Max	Min (n=3)	Mean	Max	Min (n=4)	Mean	Max	Min (n=3)	Mean
Mercury	165.0	11.0	40.0	0.7	<0.1	0.3	6.0	2.2	3.3	5.9	0.1	3.4
Arsenic	14.0	3.8	6.9	11.0	4.8	6.5	12.0	5.0	8.7	11.0	7.4	8.9
Cadmium	8.2	<0.5	1.6	8.6	<0.5	8.6	2.4	0.6	1.4	3.5	2.1	2.9
Chromium	58.0	24.0	37.0	35.0	16.0	22.0	290.0	66.0	163.0	38.0	19.0	27.0
Lead	170.0	36.0	80.0	85.0	35.0	52.0	51.0	33.0	40.0	38.0	23.0	32.0
Nickel	74.0	20.0	37.0	155.0	28.0	67.0	30.0	24.0	26.0	65.0	43.0	56.0
Silver	45.0	2.0	8.0	<1.0	<1.0	<1.0	10.0	2.0	6.0	2.0	<1.0	2.0
Zirconium	590.0	350.0	448.0	500.0	430.0	500.0	480.0	260.0	365.0	470.0	220.0	340.0

Parameter (ppm)[1]	Clinch River (Watts Bar)			Background Stations					
				Clinch River (Melton Hill)			Norris Reservoir[2]		
	Max	Min (n=4)	Mean	Max	Min (n=1)	Mean	Max	Min (n=3)	Mean
Mercury	2.8	0.3	0.8	<0.1	<0.1	<0.1	0.1	0.1	0.1
Arsenic	11.0	5.1	8.1	17.0	17.0	17.0	26.0	16.0	22.0
Cadmium	4.2	0.7	1.8	0.5	0.5	0.5	<0.5	<0.5	<0.5
Chromium	25.0	9.0	16.0	25.0	25.0	25.0	23.0	21.0	22.0
Lead	38.0	14.0	30.0	28.0	28.0	28.0	77.0	58.0	67.0
Nickel	38.0	14.0	21.0	36.0	36.0	36.0	28.0	24.0	26.0
Silver	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zirconium	890.0	400.0	650.0	230.0	230.0	230.0	270.0	180.0	220.0

[1] ppm is equivalent to mg/kg.

[2] Values for Norris Reservoir include Clinch River Miles 85.3 and 94.1 and Powell River Mile 6.0.

TABLE 16

INSTREAM CONTAMINANT STUDY - TASK 2
CRITERIA AND SELECTED DATA FOR METALS IN SEDIMENT AND SOIL

Parameter[1] (ppm)	Proposed Virginia Criteria[2]	Average Earth's Crust[3]	Mean Concentrations of Upper Tennessee River[4]	Mean Concentrations of Tributary Streams to Upper Tennessee River[5]	Mean Concentrations of Clinch River[6]
Mercury (ppm)	0.3	0.5	1.00 (<0.05-4.3)	0.25 (<0.05-0.98)	0.16[7] (<0.05-0.51)
Arsenic	-	-	12.00 (7.4-17.5)	12.20 (2.0-56.0)	8.70 (2.0-16.0)
Cadmium	-	0.2	5.50 (0.4-12.0)	1.80 (<0.4-11.0)	1.40 (<0.4 to 3.7)
Chromium	-	200.0	48.00 (14.0-86.0)	19.70 (5.0-46.0)	19.30 (6.3-44.7)
Lead	-	16.0	59.70 (<10.0-99.0)	47.90 (<3.0-300.0)	31.60 (13.1-72.0)
Nickel	-	100.0	33.60 (5.8-57.0)	22.40 (<3.3-70.0)	30.00 (16.0-70.0)
Silver	-	-	2.50 (0.5-5.0)	1.30 (0.4-2.1)	1.60 (1.3-2.0)
Zirconium	-	-	-	-	-

[1] Concentrations given in mg/kg (ppm), dry weight, range in parenthesis.
[2] State of Virginia proposed regulation for total mercury in freshwater river sediment.
[3] Y. M. Goldschmidt. Courtesy A. Muir, editor, and Clarendon Press, Oxford, publishers of "Geochemistry," average abundance of trace elements in the crust of the earth.
[4] Average concentrations in river sediment for reach from Nickajack Dam to confluence of the Holston and French Broad Rivers, TRMs 427 to 652; 24 sampling locations - 1970 to 1983, TVA STORET data.
[5] Average concentrations in river sediment for streams tributary to the Tennessee River between miles 424 and 652; 43 sampling locations 1970 to 1981, TVA STORET data.
[6] Average concentrations in Clinch River sediment above Melton Hill Dam, CRM 23.2; 12 sampling locations - 1970 to 1981, TVA STORET data.
[7] Seven of twelve samples below detection limits.

above background levels with values of 0.3 and 0.8 mg/kg, respectively. Mercury concentrations in Melton Hill Reservoir and Norris Reservoir were less than the background levels given in Table 16 for all samples.

Arsenic concentrations were present at or below background levels at all sampling stations except Melton Hill and Norris Reservoirs where mean concentrations of 17 mg/kg and 22 mg/kg, respectively, exceeded background levels of 9 to 12 mg/kg. Mean cadmium concentrations in East Fork Poplar Creek, Bear Creek, lower White Oak Creek, Poplar Creek, and the Clinch River (Watts Bar) were greater than the concentrations in Melton Hill and Norris Reservoirs, yet concentrations were within the range of background levels given in Table 16.

Chromium was present below or slightly above background levels of approximately 20 mg/kg, except for lower White Oak Creek where the mean concentration was 163 mg/kg. Lead was present within the range of background levels for all sampling locations except East Fork Poplar Creek and Norris Reservoir where mean concentrations of 80 mg/kg and 67 mg/kg, respectively, exceeded background values of 30 to 60 mg/kg. Lead concentrations in Norris Reservoir were also above the concentrations observed at downstream Clinch River locations (Table 15).

Mean nickel concentrations were at or below background levels except for East Fork Poplar Creek and Poplar Creek where mean concentrations of

67 mg/kg and 56 mg/kg, respectively, exceeded background values of 20 to 30 mg/kg. Silver concentrations were above background levels in East Fork Poplar Creek and lower White Oak Creek with mean concentrations of 8 mg/kg and 6 mg/kg, respectively, exceeding background levels of 2 mg/kg. Mean concentrations of zirconium increased significantly at the sampling locations downstream of Melton Hill and Norris Reservoirs, but no additional background data were available for comparison.

4.3.3 ORGANICS

The results of organic analyses including base/neutral priority pollutants and PCBs are included in Appendix II - Table 1. Detection limits values are followed by a "U" or "M" depending on whether evidence of the parameter presence existed (i.e., "U" indicating no evidence of parameter presence).

Since most of the organic compounds analyzed are not naturally occurring in the environment and because standards, criteria, or background data were not available (except for PCBs in fish), their presence at any level may warrant further investigation. The FDA action level for PCBs in fish is 2.0 ppm. Some fish collected for Task 4 of the Instream Contaminant Study showed concentrations exceeding this value. Thus, PCB concentrations in sediment may be of special interest.

Table 17 is a statistical summary of all PCB and base/neutral compounds which had concentrations at or above the analytical detection limit. Compounds were found above the detection limit in East Fork Poplar Creek, Bear Creek, and lower White Oak Creek. The greatest frequencies of occurrence and the highest concentrations of base/neutral priority pollutants were found in East Fork Poplar Creek with fluoranthene and bis(2-ethylhexyl) phthalate being found most often. PCBs were present at highest concentrations in lower White Oak Creek where concentrations of 1,200 µg/kg PCB 1254 and 1,600 µg/kg PCB 1260 were obtained at mile 0.3.

It should be noted that quality control split samples analyzed by EPA (Appendix V - Quality Control) showed results for base/neutral compounds that were on average 3.54 times higher than the TVA laboratory results. The reason for these differences is believed to be due to the use of a more advanced and efficient analytical procedure (gel permeation chromatograph cleanup technique) by the EPA laboratory than by the TVA laboratory (hexane acetonitrile cleanup technique).

As a supplement to the organic analyses specified in the Instream Contaminant Study workplan (1), an interpretive analysis was conducted for other organic compounds which produced significant peaks during the gas chromatograph/mass spectrometer analysis. This search resulted in the

TABLE 17

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SEDIMENT -
ORGANIC COMPOUND CONCENTRATIONS AT OR ABOVE ANALYTICAL DETECTION LIMITS

Parameter (ppb)[1]	East Fork Poplar Creek				Bear Creek				White Oak Creek			
	n[2]	Max.	Min.	Mean	n[2]	Max.	Min.	Mean	n[2]	Max.	Min.	Mean
PCB 1254	5	2,000	200	680	1	500	500	500	1	1,200	1,200	1,200
PBC 1260	9	4,000	200	850	1	900	900	900	1	1,600	1,600	1,600
Fluoranthene	9	4,600	870	1,850	1	970	970	970		-	-	-
Bis(2-Ethylhexyl) Phthalate	14	2,000	700	1,170	-	-	-	-	1	1,600	1,600	1,600
Pyrene	7	850	3,500	1,590	1	710	710	710	-	-	-	-
Phenanthrene	5	1,200	4,500	1,980	1	690	690	690	-	-	-	-
Benzo-a-Pyrene	1	900	900	900	-	-	-	-	-	-	-	-
Chrysene	1	920	920	920	-	-	-	-	-	-	-	-
Anthracene	1	1,000	1,000	1,000	-	-	-	-	-	-	-	-
Benzo-a-anthracene-1,2 Benzanthracene	2	1,200	920	1,060	-	-	-	-	-	-	-	-

[1] ppb is equivalent to µg/kg.

[2] This table provides data only for the streams with concentrations above the detection limits. "n" is the number of occurrences in a particular stream that the concentrations of a specific compound exceeded the detection limit. Max., Min., and Mean are the statistics for those concentrations at or above the detection limit only and does not include values below the detection limit.

identification of several additional (nonpriority pollutant) organic compounds. These compounds and their estimated concentrations and percent probability of a positive match with a reference spectrum of that compound are given in Appendix II - Table 2.

4.3.4 CYANIDE AND TOTAL PHENOLS

The results of cyanide and total phenol analyses are given in Appendix II - Table 1. Cyanide concentrations were below analytical detection limits for all surface layer samples and no indication of presence below the detection limit was evident (i.e., reported as the detection limit followed by a "U"). Phenols were found in all streams and reservoirs sampled with the exception of lower White Oak Creek. As with the base/neutral organics and PCBs, no standards, criteria, or background data for total phenols were available. Table 18 is a summary of total phenol concentrations at or above the detection limit. Mean concentrations for those samples exceeding the detection limit were 500 µg/kg in both Melton Hill Reservoir and Norris Reservoir. The highest total phenol concentrations existed in East Fork Poplar Creek and Bear Creek with mean concentration of 1,000 µg/kg and 1,200 µg/kg, respectively.

4.3.5 RADIOLOGICAL ANALYSES

The results of radiological analyses are presented in Appendix II - Table 1. Table 19 summarizes the maximum concentrations of significant radioisotopes for 35 surface layer, fine-particle samples collected on

TABLE 18

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SEDIMENT -
TOTAL PHENOL CONCENTRATIONS AT OR ABOVE DETECTION LIMITS

Stream	No. of Samples With Concentrations at or Above Detection Limits	Phenol (ppb)[1,2]		
		Max.	Min.	Mean
East Fork Poplar Creek	14	1,700	500	1,000
Bear Creek	3	1,300	1,000	1,200
White Oak Creek	0	-	-	-
Poplar Creek	1	400	400	400
Clinch River (Watts Bar)	2	600	600	600
Clinch River (Melton Hill)	1	500	500	500
Norris Reservoir[3]	2	500	500	500

[1] Statistics are computed only for those samples with concentrations at or above the detection limit and values below the detection limit are not included.

[2] ppb is equivalent to µg/kg.

[3] Includes background stations on the Clinch River and Powell River.

TABLE 19

INSTREAM CONTAMINANT STUDY - TASK 2
SURFACE LAYER, FINE-PARTICLE SAMPLING - MAXIMUM CONCENTRATIONS REPORTED FOR SIGNIFICANT RADIOISOTOPES IN SURFACE SEDIMENT SAMPLES (All concentrations are pCi/g, dry weight)[1]

	Clinch River	East Fork Poplar Creek	Bear Creek	White Oak Creek	Poplar Creek	Norris Reservoir Control Station: Clinch River Upstream	Norris Reservoir Control Station: Powell River	Comparison Data: Tennessee River[2]	Comparison Data: Clinch River[3]
ANALYSIS/ISOTOPE									
Gross Alpha	11	160	32	3	11	4	3	15	100
Gross Beta	398	110	150	6,600	60	42	37	65	91
Uranium[1]	7	90	200	4.1	14	5.9	2.3	–[4]	2.0
Sr-89	4	.7	.5	0	1	4	1	14	12.1
Sr-90	1.8	.1	.1	900	.2	.4	.5	.6	0.6
GAMMA SPECTRAL ANALYSIS[5]									
Co-60	1.2	–	–	184	–	–	–	.6	2.7
Cs-134	–	–	–	1.2	–	–	–	.13	.01
Cs-137	167	8.6	.2	12,100	1.9	.9	.7	5.5	83
K-40	27	21	18	25	16	27	16	27	84
Ra-226	.7	–	–	–	–	–	–	2.3	1.4
Th-234	4	23	63	–	3.8	–	–	–	–
Eu-152	–	–	–	8	–	–	–	–	–
Eu-154	–	–	–	7	–	–	–	–	–
Am-241	–	–	–	4	–	–	–	–	–
Ac-228	2.2	2	1.8	4	1.1	2.2	1.8	2.7	2.1
Pa-234	–	–	–	–	–	–	–	4.6	4.8
TRANSURANICS									
Pu-239	.73	.10	.001	1.08	.02	–[4]	–[4]	–[4]	–[4]
Pu-238	.03	.02	.001	.007	<.0002	–[4]	–[4]	–[4]	–[4]
Am-241	.51	.05	.04	.46	.02	–[4]	–[4]	–[4]	–[4]
Cm-244	.02	.01	.009	.01	<.0008	–	–	–	–

[1] Uranium reported in units of µg/g, dry weight.
[2] Maximum concentrations reported by TVA in surface sediment samples collected from the Tennessee River from 1981-83.
[3] Maximum concentrations reported by TVA in surface sediment samples collected from the Clinch River from 1974-1983.
[4] Analysis not performed.
[5] Dash indicates isotope not identified in gamma spectral analysis.

NOTE: The lower limits of detection for all isotopes, as determined by the method developed by Pasternack and Harley, and described in HASL-300 and Nucl. Inst. Methods 91, 533-40 (1971), are typically 1 pCi/g, dry weight,

East Fork Poplar Creek, Bear Creek, Poplar Creek, the Clinch River (Watts Bar Reservoir and Melton Hill Reservoir) and Norris Reservoir. Since no standards or guidelines exist for radionuclide concentrations in sediment, concentrations reported previously (1974 to 1983) by TVA from the analysis of samples from the Tennessee River and Clinch River are presented for comparison.

Nine samples were collected from the Clinch River (Watts Bar Reservoir and Melton Hill Reservoir). Samples collected in Watts Bar Reservoir indicated the presence of cesium 137 and cobalt 60 with cesium 137 being the predominant isotope reported. The highest cesium 137 concentrations were reported at miles 18.3 and 3.5 with maximum concentrations of 160 and 20 pCi/g, respectively. The sample collected at mile 18.3 consisted of two visibly different textures; therefore, it was separated into two segments, one representing the top 3 inches and the other approximately the 3 to 5 inch depth. The 3 to 5 inch segment contained the highest radioactivity concentrations reported in the Clinch River sediment samples. The sample collected in Melton Hill Reservoir (CRM 24.0) did not indicate the presence of cesium 137, and cobalt 60 was present at much lower levels (0.21 pCi/g) than in Watts Bar Reservoir. Concentrations of transuranic isotopes were found to be less than 0.73 pCi/g.

Three samples were taken from upstream control locations in Norris Reservoir (Clinch and Powell Rivers). The results from the analyses of

these samples, summarized in Table 19, generally correspond with the levels reported by TVA for samples taken from the Tennessee River.

Unlike the samples from the Clinch River (Watts Bar Reservoir), samples from East Fork Poplar Creek were found to contain little fission and activation product material (e.g., cesium 137 and cobalt 60). The presence of cobalt 60 was not indicated and cesium 137 was at or below levels reported in the Tennessee River for all but three samples which exceeded the levels in the Tennessee River by approximately 20-50 percent. Gross alpha and beta concentrations generally tended to increase with distance upstream while cesium 137 levels generally decreased. Concentrations of uranium and radionuclides in the uranium decay series were higher in East Fork Poplar Creek than at the upstream control stations in Norris Reservoir by a factor of approximately 15. Transuranic isotopes exhibited concentrations significantly less than levels reported in the Clinch River surface sediment samples.

Radioactivity concentrations in Bear Creek were similar to those in East Fork Poplar Creek, except that the concentration of uranium and uranium decay series isotopes were up to twice those in East Fork Poplar Creek and cesium 137 concentrations were less. Cesium 137 concentrations were less than the levels reported in the Tennessee River or at control stations in Norris Reservoir. Concentrations of transuranic isotopes were less than those reported in East Fork Poplar Creek.

As expected, radionuclide concentrations in lower White Oak Creek were higher than levels in other streams. Cesium 137 and cobalt 60 were the dominant isotopes with significant concentrations of strontium 90 also reported. Uranium concentrations were generally in the range of concentrations reported in Norris Reservoir. Concentrations of transuranic isotopes were similar to those reported in the Clinch River.

Three surface samples were collected from Poplar Creek. The concentrations reported were generally consistent with those reported in the Tennessee River and in Norris Reservoir. The uranium concentration in one sample, however, exceeded the concentrations in Norris Reservoir.

4.4 CLINCH RIVER AND TENNESSEE RIVER SEDIMENT

Core sampling in the Clinch River and Tennessee River was conducted primarily to determine the presence of mercury downstream of DOE facilities at Oak Ridge. Results are presented in Appendix III for the Clinch River and Appendix IV for the Tennessee River. The following sections describe the physical characteristics of the sediment samples and compare chemical and radiological results with available standards, criteria, and background levels.

4.4.1 PHYSICAL CHARACTERISTICS

4.4.1.1 CLINCH RIVER

Results of the specific gravity, particle size, and percent moisture analyses for seven sediment cores collected from the Clinch River are summarized in Table 20. Particle size distribution is presented in terms of the percent weight of each layer that is within specified size ranges. The mean percentages in each size range for the total sample are also given, indicating the particle size distribution for a homogeneous composite of all layers. Samples at Clinch River Miles 3.7, 10.0, and 15.6 were collected instream. All other cores were collected on land (mile 18.3 on Grubb Island and miles 19.7, 20.1, and 20.5 on Jones Island). Little or none of the sediment collected was in the gravel range (>2,000 micrometers). Fine sediment (<62 micrometers) ranged from 22.3 to 69.7 percent of the total core. Vertical stratification of particle size was evident at most locations, although no distinct trends with depth were apparent. Specific gravity ranged from 2.24 at mile 18.3 to 2.54 at mile 10.0.

4.4.1.2 TENNESSEE RIVER

Physical characteristics for the seven Tennessee River cores include only particle size analyses and are summarized in Table 21. Particle size distribution is given in terms of the percent weight of each layer within specified size ranges. At Tennessee River Miles 475.0 and 487.9

TABLE 20

INTENSIVE CONTAMINANT STUDY - TASK 2
CLINCH RIVER CORE SAMPLING - PHYSICAL CHARACTERISTICS OF SEDIMENT[3]

Mile	Layer[1]	Specific Gravity	% Moisture	Gravel % of Layer >2,000 µm	Coarse Sand 2,000 µm>% of Layer>500 µm	Medium to Fine Sand 500 µm>% of Layer>62 µm	Fine Sediment % of Layer <62 µm
3.7	A[2]	2.33	44	0.2	5.9	51.6	42.3
	B	-	-	1.7	7.2	25.5	65.6
	C	-	-	0	7.1	6.2	86.7
	D	-	-	0.2	7.0	55.7	37.1
			Mean	0.5	6.8	34.8	57.9
10.0	A	2.54	27	0	0.6	87.9	11.5
	B	-	-	0	1.0	21.8	77.2
	C	-	-	0	0.8	3.4	95.8
	D	-	-	0	2.5	3.2	94.3
			Mean	0	1.2	29.1	69.7
15.6	A[2]	2.50	30	0.2	5.6	70.6	23.6
	B	-	-	0	6.7	42.6	50.7
	C	-	-	0.2	7.0	72.4	20.4
	D	-	-	0	12.1	48.4	39.5
			Mean	0.1	7.9	58.5	33.5
18.3	A	2.24	23	2.1	6.2	71.4	20.3
	B	-	-	0	2.7	26.5	70.8
	C	-	-	0	3.6	32.6	63.8
	D	-	-	0	3.4	24.2	72.4
			Mean	0.5	4.0	38.7	56.8
19.7	A	2.31	30	0	0.4	69.5	30.1
	B	-	-	0	2.9	49.5	47.6
	C	-	-	0	0.9	47.0	52.1
	D	-	-	0	0.9	34.1	65.0
			Mean	0	1.3	50.0	48.7
20.1	A	2.46	13	0	0.6	85.9	13.5
	B	-	-	0	0.3	67.8	31.9
	C	-	-	0	1.3	77.6	21.1
	D	-	-	0	0.5	76.6	22.9
			Mean	0	0.7	77.0	22.3
20.5	A[2]	2.51	14	17.6	15.1	61.3	6.0
	B	-	-	0	5.0	28.6	66.4
	C	-	-	0	3.0	48.5	48.5
	D	-	-	0	3.0	39.6	57.4
			Mean	4.4	6.5	44.5	44.6

[1]Layer identifiers A, B, C, and D correspond to the sequential core segments from top to bottom of the core. A is the surface layer, B is the next deepest layer, etc. Layers were approximately 8 inches in length except those at miles 3.7 and 10.0 which were approximately 3 inches and 4 inches respectively; see Appendix III for exact lengths of core segments.

[2]Results for layer are the mean values of laboratory duplicate analyses.

[3]Sediment size classifications are from ASCE Sedimentation Engineering (11).

TABLE 21

INSTREAM CONTAMINANT STUDY - TASK 2
TENNESSEE RIVER CORE SAMPLING - PHYSICAL CHARACTERISTICS OF SEDIMENT

Mile	Layer[1]	Gravel % of Layer >2,000 μm	Coarse Sand 2,000 μm>% of Layer>500 μm	Medium to Fine Sand 500 μm>% of Layer>125 μm	Very Fine Sand 125 μm>% of Layer>62 μm	Fine Sediment % of Layer <62 μm
387.0	A	0	0.4	21.5	19.4	58.7
	B	0	0	8.2	19.6	72.2
	C	0	0	8.8	15.3	75.9
	D	0	0	5.3	14.4	80.3
	Mean	0	0	11.0	17.1	71.8
475.0	A[2]	0	0	0.2	0.1	99.7
	B	0	0	0.8	0.1	99.1
	C	0	0	0.1	0.1	99.8
	D	0	0	2.4	2.5	97.6
	Mean	0	0	3.5	0.7	99.1
487.9	A[2]	0	0.1	1.0	2.7	96.2
	B	0	0	1.0	3.7	95.3
	C	0	0	0.6	3.9	95.5
	D	0	0.2	7.7	15.1	77.0
	Mean	0	0.1	2.6	6.3	91.0
509.0	A	0	0	26.9	14.4	58.7
	B	0	0	29.6	14.0	56.0
	C	0	0	17.3	10.8	71.9
	D	0	0.5	15.3	11.5	72.7
	Mean	0	0.1	22.4	12.7	64.8
540.0	A	0	0	1.1	0.9	98.0
	B	0	0	0.5	1.6	97.9
	C	0	0	0.7	0.4	98.9
	D	0	0	0.7	0.7	98.6
	Mean	0	0	0.8	0.9	98.3
552.0	A	0	0	0	0.9	99.1
	B	0	0	0.3	0.5	99.2
	C	0	0	0	0.1	99.9
	D	0	0	0.4	0.5	99.1
	Mean	0	0	0.2	0.5	99.3
574.4	A	0	0	0.2	1.2	98.6
	B	0	0.3	32.0	22.7	45.0
	C	0	0	1.5	5.8	92.7
	D	0	0.5	8.9	22.8	67.8
	Mean	0	0.3	10.6	13.1	76.0

[1]Layer identifiers A, B, C, and D correspond to the sequential core segments from top to bottom of the core. A is the surface layer, B is the next deepest layer, etc. All layers were 4 to 6 inches in length except at miles 540 and 552 where the layers were approximately 10 inches and 12 inches, respectively; see Appendix IV for exact lengths of core segments.

[2]Results for layer are the mean values of laboratory duplicate analyses.

[3]Sediment size classifications are from ASCE Sedimentation Engineering (11).

(Chickamauga Reservoir) and at miles 540.0 and 552.0 (Watts Bar Reservoir) more than 90 percent of the core sediments consisted of fine sediments (<62 micrometers) with little vertical stratification. At Tennessee River Miles 387.0 (Guntersville Reservoir), mile 509.0 (Chickamauga Reservoir), and mile 574.4 (Watts Bar Reservoir upstream of Clinch River), particle size distribution was more variable.

4.4.2 MERCURY

4.4.2.1 CLINCH RIVER

Results of mercury analyses for three cores collected instream, one core collected on Grubb Island, and three cores collected on Jones Island are presented in Appendix III - Table 1. Concentrations are reported for the size fractions less than 500 μm and less than 62 μm. Detection limit values are followed by a "U" symbol indicating no evidence of mercury below the detection limit. All concentrations are expressed as the mass of mercury, mg, per unit mass of dry sediment, kg, of a given size (<62 μm or <500 μm). Sediment sizes <500 μm constituted 90 percent or greater of the total sample for each core collected (Table 20 and Appendix III).

Histograms of mercury concentration versus depth are presented in Appendix III - Figure 1 for each sampling location. Table 22 summarizes the surface layer and maximum concentrations (<500 μm size fraction);

TABLE 22

INSTREAM CONTAMINANT STUDY - TASK 2
CLINCH RIVER CORE SAMPLING - SUMMARY OF MERCURY RESULTS
AND COMPARISON TO PREVIOUS ORNL CORE DATA

Location	Surface Layer Concentration (mg/kg)	Highest Concentration (mg/kg)	Sediment[1] Covering Highest Concentration (inches)	Core Penetrated to Background[2]
CRM 15.6	0.1	0.5	5.5	Yes
(CRM 11.0)[3]		180.0		
CRM 10.0	0.7	0.8	4.0	Yes
(CRM 6.8)[4]	3.8	13.2	32.0	Yes
CRM 3.7	3.8	12.0	30.7	No
(CRM 1.0)[4]	3.0	46.0	39.0	No
Grubb Island (CRM 18.3)	<0.1	<0.1	0	Yes
Jones Island				
CRM 20.5	<0.1	<0.1	0	Yes
CRM 20.1	<0.1	<0.1	0	Yes
CRM 19.7	<0.1	<0.1	0	Yes

[1]Depth of sediment covering the layer of highest mercury concentration.

[2]Background concentration is 0.2 mg/kg based on Table 16 for mean concentrations of the Clinch River and tributaries to the Upper Tennessee River.

[3]Data collected by ORNL in 1977 (9).

[4]Data collected by ORNL in 1983 (9).

the depth of sediment covering the layer of highest concentration; and whether or not the core penetrated to background levels (0.2 mg/kg, Table 16). The results of three instream cores collected at miles 11.0, 6.8, and 1.0 by ORNL during 1977 and 1983 are also given for comparison. Comparison of data for the <500 μm size fraction with the proposed criteria and background levels given previously in Table 16 shows that maximum concentrations on Jones Island and Grubb Island were at or below 0.2 mg/kg. Maximum concentrations for the instream cores collected at miles 15.6 and 10.0 were above 0.2 mg/kg, but were within the range of mean levels of the Clinch and Tennessee Rivers (0.2-1.0 mg/kg, Table 16). The highest mercury concentrations were reported at mile 3.7 with a maximum concentration of 12.0 mg/kg in the lower core layer (24 to 30 inch depth). All cores except the core collected at mile 3.7 penetrated to the depth of background concentrations. The data obtained by TVA at mile 3.7 is similar to the data obtained by ORNL at mile 6.7. Maximum mercury concentrations in the Clinch River sediments increased substantially downstream of Poplar Creek.

4.4.2.2 TENNESSEE RIVER

Appendix IV - Table 1 presents the results of mercury analyses of three cores collected in Watts Bar Reservoir, three in Chickamauga Reservoir, and one in Guntersville Reservoir. Concentrations are reported for the total sample. Detection limit values are followed by a "U" symbol indicating no evidence of mercury below the detection limit.

Histograms of total mercury concentration and corresponding cesium 137 activity versus depth are presented in Appendix IV - Figure 1. Cesium 137 activities were counted by ORNL using the same core samples which were analyzed for mercury. Table 23 summarizes the surface layer and maximum mercury concentrations; the depth of sediment covering the layer of highest concentration; and whether or not the core penetrated to background levels (0.2 mg/kg). The results of four cores collected at miles 550.0, 538.0, 502.0, and 472.0 by ORNL during 1983 are also given for comparison. Maximum mercury concentrations are substantially above background levels at all locations except miles 509.0 in Chickamauga Reservoir and mile 574.4 (control station in Watts Bar Reservoir upstream of the Clinch River confluence). The highest mercury concentrations were reported at mile 540.0 with a maximum concentration of 7.8 mg/kg in the 31.5 to 33.5 inch (80 to 85 cm) depth layer. Cores collected during this study which did not penetrate to background levels included those collected at miles 574.4 (control station), 552.0 in Watts Bar Reservoir, and mile 475.0 in Chickamauga Reservoir.

Cesium 137 activities have been used as a means of identifying mercury contaminated sediments related to past releases of mercury from ORNL. Comparison of cesium 137 activities with mercury concentrations (Appendix IV - Figure 1) show that in most cases increases in mercury with depth are associated with increases in cesium 137 activities. Peak

TABLE 23

INSTREAM CONTAMINANT STUDY - TASK 2
TENNESSEE RIVER CORE SAMPLING - SUMMARY OF MERCURY RESULTS AND COMPARISON TO PREVIOUS ORNL DATA

Location	Surface Layer Concentration (mg/kg)	Highest Concentration (mg/kg)	Sediment[1] Covering Highest Concentration (inches)	Core Penetrated to Background[2]
		WATTS BAR RESERVOIR		
TRM 574.4 Control Station	0.1	0.3	27.7	No
TRM 552.0	1.3	7.5	37.4	No
(TRM 550.0)[3]	<1.0	14.0	36.0	Yes
TRM 540.0	0.7	7.8	31.5	Yes
(TRM 538.0)[3]	<0.5	7.0	14.0	Yes
		CHICKAMAUGA RESERVOIR		
(TRM 502.0)[3]	<0.35	0.5	30.0	No
TRM 509.0	0.3	0.7	9.8	Yes
TRM 487.9	0.5	2.6	13.8	Yes
TRM 475.0	0.6	3.0	13.8	No
(TRM 472.0)[3]	<0.7	3.5	14.0	Yes
		GUNTERSVILLE RESERVOIR		
TRM 387.0	0.5	0.5	2.0	Yes

[1]Depth of sediment covering the layer of highest mercury concentration.

[2]Background concentration is 0.2 mg/kg based on Table 16 for mean concentrations of the Clinch River and tributaries to Upper Tennessee River.

[3]Data collected by ORNL in 1983 (9).

mercury concentrations also occurred at depths where cesium 137 activities peaked for all samples except those collected at miles 475.0 and 487.9 in Chickamauga Reservoir downstream of the Hiwassee River confluence.

4.4.3 PCB AND CHROMIUM

PCB and chromium analyses were performed for the seven cores collected from the Tennessee River. These results are presented in Appendix IV. PCB was below detection limits for all samples and no evidence of its presence was detected analytically.

Table 24 summarizes the surface layer and maximum chromium concentrations; the depth of sediment covering the layer of highest concentration; and whether or not the core penetrated to background levels of approximately 20 mg/kg. Previous data collected by TVA in this reach of the Tennessee River showed chromium concentrations above the background levels of tributary streams (i.e., 48 mg/kg in the Tennessee River and approximately 20 mg/kg in tributary streams - Table 16). The maximum concentrations shown in Table 24 exceed 20 mg/kg but are consistent with previous data from this section of the Tennessee River.

4.4.4 RADIOLOGICAL ANALYSES

The results of radiological analyses for eight core samples collected in the Clinch River (Watts Bar Reservoir) are presented in Appendix III - Table 1). Table 25 summarizes the maximum concentrations of significant

TABLE 24

INSTREAM CONTAMINANT STUDY - TASK 2
TENNESSEE RIVER CORE SAMPLING - SUMMARY
OF CHROMIUM RESULTS

Location	Surface Layer Concentration (mg/kg)	Highest Concentration (mg/kg)	Sediment[1] Covering Highest Concentration (inches)	Core Penetrated to Background[2]
		WATTS BAR RESERVOIR		
TRM 574.4 Control Station	26[3]	38[3]	31.5	No
TRM 552.0	35	50	17.7	No
TRM 540.0	42	54	23.6	No
		CHICKAMAUGA RESERVOIR		
TRM 509.0	23	29	4.7	Yes
TRM 487.9	34	39[4]	26.4	No
TRM 475.0	45	45[4]	0	No
		GUNTERSVILLE RESERVOIR		
TRM 387.0	22	26	16.5	Yes

[1]Depth of sediment covering the layer of highest chromium concentration.

[2]Background concentrations are approximately 20 mg/kg based on Table 16 for mean concentrations of the Clinch River and tributaries to the Upper Tennessee River.

[3]Concentrations represent the mean of field duplicate samples.

[4]Chromium concentrations vary only slightly with depth.

TABLE 25

INSTREAM CONTAMINANT STUDY - TASK 2
CLINCH RIVER CORE SAMPLING - MAXIMUM CONCENTRATIONS REPORTED FOR SIGNIFICANT RADIOISOTOPES IN CORE SAMPLES[1]
(All concentrations are pCi/g, dry weight)

	Clinch River Instream	Jones and Grubb Islands	TENNESSEE RIVER[2]
ANALYSIS/ISOTOPE			
Gross Alpha	14	10	15
Gross Beta	111	100	65
Uranium[1]	5.1	1.3	--[3]
Sr-89	3	3	14
Sr-90	0.1	0.1	0.6
GAMMA SPECTRAL ANALYSIS			
Co-60	1.6	--[4]	0.6
Cs-137	42	3.2	5.5
K-40	44	44	27
Ra-226	0.9	0.9	2.3
Th-234	4	1.4	--[4]
Ac-228	1.5	0.9	2.7
TRANSURANICS			
Pu-239	0.1	0.02	--[3]
Pu-238	0.01	<0.001	--[3]
Am-241	0.30	0.02	--[3]
Cm-244	0.05	0.007	--[3]

[1]Uranium reported in units of µg/g, dry weight.

[2]Maximum concentrations reported by TVA in surface sediment samples collected from the Tennessee River from 1981-83.

[3]Analyses not performed.

[4]Isotope not identified in gamma spectral analyses.

NOTE: The lower limits of detection for all isotopes, as determined by the method developed by Pasternack and Harley, and described in HASL-300 and Nucl. Inst. Methods 91, 533-40 (1971), are typically 1 pCi/g, dry weight, or less.

radioisotopes. Since no standards or guidelines exist for radionuclide concentrations in sediment, concentrations reported previously (1981 to 1983) by TVA from the analysis of samples from the Tennessee River are presented for comparison.

Samples collected on Grubb Island (CRM 18.3) and Jones Island (CRM 19.7, 20.1, 20.5, and 20.6) revealed concentrations in the range of those reported for the Tennessee River, indicating no significant contamination on the islands. The gross beta activity of these samples increased slightly with depth to about 26 inches and then decreased. The instream core samples collected on the Clinch River (CRM 3.7, 10.0, and 15.6) indicated the presence of cesium 137 and cobalt 60 with cesium 137 being the predominant isotope reported. The highest cesium 137 value among these core samples was reported at CRM 3.7. Gross beta concentrations in these samples generally increased with depth with the highest conentration also reported at CRM 3.7.

4.5 QUALITY CONTROL

4.5.1 INTRALABORATORY CONTROL CHARTS

Intralaboratory control charts for all parameters analyzed (with the exception of organic priority pollutants) were maintained as described in Section 3.5.1. Duplicate and spiked samples were either within the "control limits" or when "out-of-control" situations occurred, all the samples within that batch were reanalyzed.

4.5.2 REFERENCE SAMPLES

Reference samples were inserted (for those parameters where reference material was available) into the analytical stream as described in Section 3.5.2. These samples were periodically analyzed to assess the accuracy of the analytical measurements. The results of these analyses are tabulated in Appendix V - Table 1.

Although the 95 percent confidence interval of the mean recovery for many of the parameters does not encompass 100 percent, no significant bias was exhibited for any of the parameters analyzed.

4.5.3 BLIND DUPLICATE SAMPLES

4.5.3.1 BLIND FIELD DUPLICATES

Blind field duplicates were prepared and inserted into the analytical stream as indicated in Section 3.5.3.1. Results of these duplicate samples are summarized in Appendix V - Table 2 for nonradiological analyses and in Table 3 for radiological analyses.

For nonradiological analyses the mean relative standard deviation calculated from the results of the field duplicate data for each parameter ranges from a low of 1.1 percent for particle size (<2.0 μm) to a high of 62.2 percent for mercury on the less than 6.35 mm fraction. The mean RSD for all measurements is 22.9 percent. This value when compared to an

overall mean of 11.6 for the mean of the laboratory duplicates (Section 4.5.3.2) indicates significant variability within the sediment samples.

To allow the analyses of a greater number of mercury samples, most analyses were performed on a single aliquot rather than a triplicate determination. The precision of single aliquot mercury determinations is less than the triplicate determinations of field duplicates. Although only eight field duplicates were analyzed in triplicate (as opposed to 91 duplicates with singly determined mercury), the mean RSD is significantly less. The mean RSD for mercury on the singly determined duplicates is 57.5 percent compared to 24.6 percent for those analyzed in triplicate. The overall mean RSD for mercury on field duplicates is 54.8 percent. When this is compared to a value of 20.3 percent for the laboratory duplicates it appears that the most significant variability in the field duplicates is natural variability in the environment and the resulting inability to collect truly duplicate samples.

Duplicates of nine separate samples from six different locations representing both surface and core sediment samples were submitted to the TVA Western Area Radiological Laboratory (WARL) for analysis. The results presented in Appendix V - Table 3 show general agreement, although some variations exceeded those typically encountered in TVA's Interlaboratory Comparison Program with EPA. The variation in results are believed to be

influenced to a greater extent by natural variability in the environment and the inability to collect truly duplicate samples than by analytical procedures.

4.5.3.2 BLIND LABORATORY DUPLICATES

Blind laboratory duplicates were prepared and inserted into the analysitcal stream as described in Section 3.5.3.2. Results are summarized in Appendix V - Tables 2 and 4.

The mean RSD, calculated from the data of the paired laboratory duplicates for each parameter, ranges from a low of 0.7 percent for total PCB to a high of 39.7 percent for particle size (<0.5 μm). The mean RSD for all measurements is 11.6 percent. The wide range of results for the RSD is due to the lack of sample homogeneity, differences in the reproducibility of each analytical methodology, and the concentration of the parameters measured. An example where concentration has a significant effect on RSD is seen in the results for silver. A percent RSD of 22.6 was obtained; however, the mean concentration of the duplicates measured was only 13 mg/kg which is only an order of magnitude higher than the detection limit. This also accounts for the high RSD values for other determinations such as arsenic, cadmium, nickel, oil and grease, and total phenol.

As with the field duplicates, most mercury analyses were performed on a single aliquot rather than a triplicate determination. Although this had an impact on the precision of the data, the results are consistent with the purposes of this study. The mean RSD for all the singly determined mercury values is 24.5 percent compared to 13.1 percent for the samples where the mercury concentration was determined in triplicate. The overall mean RSD for mercury results for all size fractions is 20.3 percent.

A total of five blind laboratory duplicates were analyzed for base/neutral organic compounds. A tabulation of results for the detectable compounds are listed in Appendix V - Table 4. The large variation between the laboratory duplicates is due to the difficulty in obtaining a truly homogeneous sample and the analytical methodology that is currently available for the analysis of priority pollutants in sediment.

4.5.4 EPA SPLIT SAMPLES

Split samples were prepared and shipped to the EPA Region IV laboratory for nonradiological analyses and to the EPA Eastern Environmental Radiation Facility (EERF) for radiological analyses as described in Section 3.5.4. Results on the split samples are listed in Appendix V - Table 5 and summarized in Appendix V - Table 6 for nonradiological analyses and in Appendix V - Table 7 for radiological analyses.

Results of the EPA-TVA split sediment analyses agree in finding most parameters below detection limit values. A significant bias between the two laboratories does exist for several parameters, however. The greatest bias is for analysis of the base/neutral compounds. The EPA results average 3.54 times higher than the TVA values. One explanation for this difference is TVA's use of the hexane-acetonitrile cleanup technique which is prescribed in EPA's interim methods for analysis of extractable organic priority pollutants in sediment. EPA-Region IV used the recently developed more efficient gel permeation chromatograph for this cleanup step. TVA's apparent loss of the compounds in the cleanup step is substantiated by an average of only 53 percent recovery on spike samples. Slight differences between the two laboratories also exist in the duplicate results for cadmium, lead, and silver.

Five sediment samples were split with EPA's EERF for analysis of radiological parameters. The results are presented in Appendix V - Table 7, showing good general agreement between the laboratories.

For gamma analysis of sediment samples, each laboratory reported isotopes not identified by the other. In one case, uranium 235 was identified by WARL from gamma spectral analysis and by EPA from uranium isotopic analysis. The uranium by fluorometry results from WARL are reported in micrograms, while the data reported by EPA are in picocuries. If uranium isotopes are present in naturally occurring ratios, the following equation may be used to convert between total picocuries and micrograms:

$$0.65 * \text{picocuries} = \text{micrograms}$$

4.5.5 CONCLUSIONS

As indicated by the duplicate and split sample results, the accuracy and precision for most of the sediment data are acceptable. The quality control program did, however, point out that, as expected, reducing the number of sample aliquots for mercury determination to collect more core samples resulted in a deterioration in the precision of the laboratory analyses. When the results of the laboratory duplicates are compared to the field duplicates, it is apparent that the most significant variability is due to natural variability in the environment. Variations in deposition patterns for sediment, even in localized areas, and the particulate nature of sediment samples, make collecting truly duplicate samples difficult and increase the value of additional core samples.

Statistically poor results were obtained on both the duplicate and split samples for the analysis of the base/neutral organic compounds. TVA's intralaboratory quality control data along with discussions with EPA chemists indicate that losses of some organic compounds may have occurred during TVA's sample cleanup, due to the analytical methodology currently available for the analyses of organics in sediment samples. These compounds could, therefore, be present in the environment at a higher concentration than indicated by the TVA results.

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